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Morton *International*

FEDERAL EXPRESS

February 21, 1990

Mr. Preston M. Canzius
New Jersey Compliance Branch
U.S. Environmental Protection Agency
Region II
Room 747
26 Federal Plaza
New York, New York 10278

Subject: Response for Thiokol Corporation
Request for Information
Rockaway Borough Wellfield Site
Morris County, New Jersey

Dear Mr. Canzius:

Morton International, Inc. ("MII") received the subject January 17, 1990 information request, addressed as follows, on January 22, 1990:

Arthur Slesinger, Director
Environmental Services
Morton International
110 North Wacker Drive
Chicago, IL 60606

As reflected by the enclosed materials, the correct recipient of the subject request and any other correspondence is:

Darryl J. Lee, Esquire
Thiokol Corporation
2475 Washington Boulevard
Ogden, Utah 84401

MII's Environmental Affairs Department was requested to provide services to Thiokol Corporation ("Thiokol") on an interim basis until otherwise directed by Thiokol. Accordingly, I prepared the attached response on behalf of Thiokol.

RWY 002 1354

In order to expedite communications regarding this matter, it is requested that a copy of any materials submitted to Thiokol be transmitted to:

Arthur Slesinger, Director
Environmental Affairs
Morton International, Inc.
110 North Wacker Drive
Chicago, IL 60606

If you have any questions regarding this response, please telephone me at (312) 807-2158.

Very truly yours,

William K. Weddendorf
Manager, Corporate Hazardous Materials
Morton International, Inc.

WKW/vt

cc: Darryl J. Lee, Esq. - Thiokol Corporation

Joseph McVeigh
Office of Regional Counsel
USEPA - Region II
Room 312

Arthur E. Slesinger - MII

Obtaining pertinent information within the prescribed 30 day time period was difficult as operations in Rockaway Borough New Jersey, by a corporate predecessor to the Thiokol Corporation, were terminated in the normal course of business.

At this time, no current employees are known to have been involved with, or knowledgeable of, the management of wastes that might have been generated at the location of interest. Pursuant to the USEPA's instructions, we have initiated efforts to: (1) locate, retrieve and review additional files from long-term storage that might, perhaps, contain relevant documents and (2) locate and contact current or former employees that may be able to provide additional information. Accordingly, this submittal will be updated as appropriate.

If the agency has ready access to certain information and/or documents noted in this submittal, the nature of this information and/or documents and their possession are indicated. With this exception, copies of all documents (or for the sake of brevity, excerpted pages/sections thereof) that relate to the questions have been attached.

The following numbered paragraphs address the correspondingly identified specific information requests in the USEPA's January 17, 1990 letter.

1. a. The correct legal name of the involved company is Thiokol Corporation ("Thiokol"). The response has been prepared by Morton International, Inc. ("MII"). Refer to paragraphs no. 2, 6 and 16 for information concerning operational history at the location and the relationship between MII and Thiokol.

   b. The name(s) and address(es) of the President and/or Chairman of the Board, or other presiding officers of Thiokol are:

      Robert T. Marsh, Chairman of the Board

      U. Edwin Garrison, President

      Thiokol Corporation
      2478 Washington Boulevard
      Ogden, UT 84401

   c. Thiokol is incorporated in the state of Delaware and its agent for service of process in the state of incorporation and in New Jersey is The Corporation Trust Company.

d. A copy of Thiokol's "Restated Certificate of Incorporation" is attached as Exhibit No. 1.

e. As Thiokol is not a subsidiary or affiliate of another corporation, it is unnecessary to identify those related companies. However, refer to paragraphs nos. 2 and 16 for supplementary information regarding operations that relate to this matter.

f. The state of incorporation and agents for service of process in the state of incorporation and New Jersey for each company identified in paragraphs nos. 1(e), 2 and 16 have not yet been identified.

2. The basis for the following discussion is information in paragraph no. 16. We are currently unable to provide all the information requested in Question 1, except for the below-noted names in response to Question 1(a):

- Reaction Motors, Inc.
- Rockefeller Family and Associates
- Chase National Bank
- Olin Corporation
- US Navy and Air Force

MII is collecting the information required by this question for these PRPs in order that they may be contacted by the Agency.

3. Thiokol's current facilities have numerous permits and identification numbers issued pursuant to the Resource Conservation and Recovery Act ("RCRA"); the company does not have a single USEPA Identification Number. In view of the focus of this response upon Rockaway Borough, a detailed recitation of Thiokol's identification numbers is not believed to be necessary nor applicable since the cessation of activities by Thiokol-related companies predated the enactment of RCRA.

4. Locations, believed to be leased in Rockaway Borough, were occupied by Reaction Motors, Inc. ("RMI") and other firms. Except for the most recent tenants, as noted in paragraph no. 16, we have no information regarding the use of the properties by firms, unrelated to RMI and its

successors, before and after the time of occupancy by RMI and its successors.

A sentence at the bottom of the first column of page 4 of the enclosed paper, "Reaction Motors, Incorporated From December 1941 through April 1958" (Exhibit No. 2) notes that RMI shifted certain functions to a location at Elm and Stickle Streets in Rockaway in 1949. We have no current way of verifying the contents of this report in order to ascertain its accuracy.

Comparing the attached copy of a print, entitled "Site Plan, Rockaway and Denville Facilities", (Exhibit No. 3) against a commonly available county map, shows that buildings along Stickel Avenue and Pine Street were in the past owned, operated, leased or maintained by Thiokol in Rockaway Borough, Morris County, New Jersey. This print is supplemented by enclosed "Figure 3-17, Location of Thiokol-RMD Facilities" (Exhibit No. 4) which was excerpted from a booklet relating to an "Inventory of Personal Property Located at Lake Denmark Test Site, Rockaway Township, New Jersey Owned by Thiokol Corporation". This document has not been included in its entirety as it is entirely relates to the "Test Area" about 10 miles north of Rockaway Borough.

We are still searching for all relevant documentation, including leases, deeds or other materials which relate to such premises. Exhibit No. 5 consists of a lease agreement between Thiokol Corporation and Klockner et. al. for property bounded by Elm Street and Stickel Avenue in the Borough of Rockaway. Exhibit No. 6, from the owner's Site Evaluation Submission notes the general history of the building which was constructed in 1946. Exhibit No. 7, from the same package, presents a sketch of the building and shows current tenants.

Other related enclosed materials are discussed in Paragraph no. 6.

5. MII does not have information that provides the exact lot and block numbers of all of RMI and Thiokol's past operations in Rockaway Borough, Morris County, New Jersey. Exhibit No. 5 indicates that the lease involved Lots nos. 37, 38, 39 and 40. Exhibit No. 7, appears to indicate that the building occupies Lots Nos. 1 and 6 of Block No. 5.

We believe that RMI and Thiokol had operations at, some or all of, the below-noted locations from 1949 until 1968.

6. Exhibit No. 8, comprised of excerpted sections of reports entitled "Site Plans, Reaction Motors Division, Thiokol Chemical Corporation, December 1958" and "Site Plans, Reaction Motors Division, Thiokol Chemical Corporation, 30 June 1959" notes the locations and floor plans of the following facilities in Rockaway Borough:

- Building No. 8 — Beech Street

  Appears to have been used for administrative purposes in 1958.

- Building No. 10 — Pine Street

  Occupied in 1959 by a catapult assembly facility and storage.

- Building No. 11 — Post Office

  Utilized for administrative purposes in 1959.

- Building No. 12 — Stickle Avenue

  In 1959, housed offices, cafeteria and "services".

- Building No. 13 — Elm Street

  In 1959, housed offices, cafeteria and "services".

- Building No. 14 — (near Elm Street)

  In 1959, occupied by laboratory and "services".

The 1963-6 "Site Plan, Rockaway and Denville Facilities", provides more legible descriptions of some of the above-noted past operations of Thiokol in Rockaway Borough along Pine Street and Stickle Avenue as follows:

- Building 10 - "Manufacturing"
- Building 12 - "Manufacturing"
- Building 13 - "Manufacturing"
- Building 14 - "Compressed Air & Power Dis."

Except as specifically indicated on the attached 1966 "Equipment Layout" prints for "Thiokol Chemical

Corporation, Reaction Motors Division, Denville, New Jersey", we are unable to further describe all manufacturing, research and development, processing and/or handling activities within these locations:

- o "Bullpup 'B' Production Facility, First Floor Plan, Building No. 10, Rockaway, N.J." (Exhibit No. 9)
- o "Bullpup 'B' Production Facility, First Floor Plan, Building No. 12, Rockaway, New Jersey" (Exhibit No. 10)
- o "Building No. 13, Rockaway, New Jersey" (Exhibit No. 11)

For your information, enclosed excerpted annual reports for 1958, 1959, 1960, 1961, 1962, 1963, 1964, 1965, 1966, 1967 and 1968 (Exhibit No. 12) identify that rockets/rocket motors were produced for the US Navy and Air Force under the "Bullpup", X-15 high altitude/speed research aircraft, and other programs. As an example of the location's defense orientation, approximately 40,000 Bullpup missiles were fabricated.

We have no known records that will enable us to ascertain, for each type of operation described in the answer to this question, the: name(s), and job description(s) of the person or persons responsible for the management of that particular operation. As such involved person(s) are no longer believed to be employed by the company, we are not able provide their last known address(es) at this time. I am continuing my efforts in this matter, and a response will be provided to the agency if appropriate.

7. We have yet to locate any information which indicates that RMI and/or Thiokol has in the past generated, purchased, used and/or handled in any manner trichloroethylene ("TCE"), perchloroethylene ("PCE"), xylene and/or any other halogenated organic chemicals in its operations within Rockaway Borough.

Thus a response to the following questions cannot be provided:

a. During what years did RMI and Thiokol generate, purchase, use and/or handle TCE, PCE, xylene and/or other halogenated organic chemicals?

b. For what purpose was TCE, PCE, xylene and/or any other halogenated organic chemicals generated, purchased, used and/or handled by RMI and Thiokol?

c. What was the volume of TCE, PCE, xylene and/or any other halogenated organic chemicals generated, purchased, used and/or handled by RMI and Thiokol on an annual basis?

Refer to Paragraph 16 for additional discussion.

8. As a result of the lack of information, we are unable to describe all storage and disposal practices employed by RMI and Thiokol with respect to all hazardous substances, hazardous wastes and/or "CERCLA waste materials" including, but not limited to, mixtures, solvents and degreasers handled in any way in RMI and Thiokol's operations in Rockaway Borough from the time operations commenced until the present. We cannot include all on-site and off-site storage and disposal activities.

In view of the emphasis of the information request upon the use of halogenated organic chemicals, inspection of the "Bullpup 'B' Production Facility, First Floor Plan, Building No. 12, Rockaway, New Jersey" reveals a location for a "degreaser". A similarly noted blueprint was reviewed during a January 21, 1988 visit by MII to the building where the degreasing operation was apparently located. This blueprint is in the possession of:

Joseph Klockner
c/o Dennis Krumholz, Esq.
Hyland & Perretti
Headquarters Plaza
One Speedwell Avenue
CN 1981
Morristown, NJ 07960

The attached copies of photographs (Exhibit No. 13) show: (1) the relative sizes of Mr. Klockner and the pit where the degreaser was located and (2) the nominal amount of debris that has collected upon the concrete floor of the pit.

Refer to Paragraph No. 16 for additional information.

9. Similarly, we are unable to indicate if RMI and Thiokol used lagoons, impoundments and/or storage tanks to treat, store and/or dispose of hazardous materials, hazardous waste or "CERCLA waste materials" and the following:

a. The installation date of said unit(s):

b. The use of said unit(s):

c. Indicate whether hazardous substances, hazardous wastes and/or CERCLA waste material were stored/disposed in said unit(s), and

d. The disposition of said unit(s).

Refer to Paragraph No. 16 for addition discussion.

10. As noted above, we are unable to provide a copy of any documents relating to the generation, purchase, use, handling, hauling, and/or disposal of all hazardous substances, hazardous wastes and/or "CERCLA waste material" identified in response to questions 7, 8, 9 and 10 above.

11. We currently have no documents nor information relating to the date of any releases of hazardous substances, hazardous wastes and/or "CERCLA waste material" including any TCE, PCE, xylene and/or any other halogenated organic chemicals at the RMI and/or Thiokol property. We are unable to provide details of the ultimate disposal of contaminated materials.

12. We currently know of no person other than Mr. Klockner (including company, individual, partnership, etc.) having knowledge of the facts relating to the generation and/or disposal of hazardous substances, hazardous wastes and/or "CERCLA waste material" identified in response to questions 7, 8, 9 and 10 above. If this situation changes, we will provide the name, address and telephone number of involved person(s) that person and the basis of our belief that he or she has such knowledge.

13. We know of no leases, contracts, permits or other written agreement relating to the generation, handling, transport and/or disposal of all hazardous substances, hazardous wastes and/or "CERCLA waste material" at RMI and Thiokol's facility in Rockaway Borough, New Jersey.

14. We are actively seeking any agreements or contracts (other than an insurance policy) which may indemnify RMI and Thiokol, present owners of shares in the company or past owners of shares in the company, for any liability that may result under CERCLA for any release or threatened release of a hazardous substance at the Site. If such agreements or contracts exist, we will provide a

copy of the agreement or contract or identify any agreement or contract that we are unable to locate or obtain.

15. We believe that Thiokol has insurance polic(y/ies), issued by the AEtna Casualty & Surety Company, Continental Casualty Company and the International Insurance Company that have been in effect which will indemnify the company against any liability which it may have under CERCLA for any release or threatened release of a hazardous substance that may have occurred at the location. Cop(y/ies) of the involved polic(y/ies) will be provided after they are obtained from counsel. Exhibits Nos. 14, 15, and 16 identify the policy numbers and years in effect.

16. Refer to the above-noted responses which may help EPA to identify sources who disposed of hazardous substances, hazardous wastes and/or "CERCLA waste material" at the Site.

Supplementary Response to Question No. 2

The following discussion considers companies that no longer exist; for those, we are currently unable to provide all the information called for in Question 1, including the agent for service of process. As the business at the location may have continued during several company names, each name is designated below.

Locations, believed to be leased in Rockaway Borough as discussed in paragraph no. 4, were occupied by Reaction Motors, Inc. ("RMI") and other firms. Except for the most recent tenants, as noted in paragraph no. 7, we have no information regarding the use of the properties by firms unrelated to RMI.

From the paper, entitled "Reaction Motors, Incorporated From December 1941 through April 1958", RMI was formed and incorporated in 1941. With respect to the Agency's search for PRPs, it should be noted that:

- This document states that, due to RMI's financial problems in 1947, the US Navy contacted Mr. Laurence S. Rockefeller who apparently arranged, through the Chase National Bank and the First National Bank of Paterson, New Jersey, an agreement that involved the purchase of notes with warrants for subsequent stock purchase.

The paper clearly states that Rockefeller exercised personal control over RMI in that he was instrumental in the appointment of a member of the Rockefeller staff to serve as RMI's Executive Vice President and General Manager from 1947 until at least 1952. Rockefeller's continuing control over RMI is indicated by RMI's 1955 list of Directors in which two of the ten members were Rockefeller employees.

- In November 1953, the Mathieson Chemical Corp. bought 50% of RMI's outstanding stock and hence a controlling interest in the company. In May 1954, Olin Industries, Inc. and Mathieson Chemical merged into the Olin Mathieson Chemical Corp ("Olin").

  Olin's control over RMI is indicated by RMI's 1955 list of Directors in which four of the ten members were Olin employees.

- As noted in paragraph no. 6, RMI's activities were those of a defense and aerospace contractor. On behalf of Thiokol, we are researching the history of the involved contracts with the US Navy and Air Force.

The titles of the personnel involved with RMI notes Olin's Aviation Division in 1955 and a Olin's High Energy Fuels Division in 1958. Thus, Olin has the potential for intimate involvement with the day-to-day operations of RMI.

RMI's merger with Thiokol Chemical Corporation occurred on April 30, 1958. As noted in the document, this action required the approval of RMI's two principal stockholders, Laurence Rockefeller and Olin whose Executive Vice President was Chairman of RMI's Board of Directors. RMI became Thiokol's Reaction Motors Division. A decrease in liquid-propelled rocket activities apparently resulted in the cessation of the Division's operations in about 1968.

In 1973, Thiokol Chemical Corporation changed its name to Thiokol Corporation which merged with Morton-Norwich Products, Inc. in 1982 to form Morton Thiokol, Inc. Effective July 1, 1989, Morton Thiokol, Inc. restructured itself by changing its name to Thiokol Corporation and redirected its activities towards defense/aerospace-related activities; commercial activities were spun off to Morton International, Inc. a newly formed Indiana Corporation.

On the basis of its corporate lineage and current activities, it is appropriate that Thiokol be contacted by the USEPA for information regarding this location. However, as part of the restructuring effort, MII agreed to provide the services of its Environmental Affairs Department to Thiokol on an interim basis. Preparation of this information request is being done under Thiokol's authority pursuant to the aforesaid agreement.

Supplementary Response to Question No. 7

With respect to the use of other halogenated organic chemicals in its operations within Rockaway Borough, the attached Site Evaluation Submission (Exhibit No. 17), by a current tenant (Multiform Metals Division of Masden Industries) at the Elm Street and Stickle Avenue property, to the NJDEP's Bureau of Industrial Site Evaluation, notes the storage and usage of methylene chloride and trichloroethylene.

The enclosed draft report, entitled "Sampling Plan Results, Masden Industries, Multiform Metals Division, ECRA Case #85551" (Exhibit No. 18), noted that elevated concentrations of volatile organics in the downgradient monitoring wells are probably attributable to the "waste oil tank" (which was recently removed) and the "catch basin/storm sewer line along the northern part of the building". We are continuing our review of this voluminous submittal which is in the possession of the Bureau of Industrial Site Evaluation of the New Jersey Department of Department Protection.

Supplementary Response to Question No. 8

With respect to all storage and disposal practices employed regarding all hazardous substances, hazardous wastes and/or "CERCLA waste materials" including, but not limited to, mixtures, solvents and degreasers handled in any way in Rockaway Borough from the time operations at the location commenced until the present, MII notes that several barrels of fresh chlorinated solvent(s) were observed being stored for use by current tenants on January 21, 1988.

The attached Site Evaluation Submission Response by the NJDEP (Exhibit No. 19) notes wastes that were stored by a tenant.

Supplementary Response to Question No. 9

Regarding the use of lagoons, impoundments and/or storage tanks to treat, store and/or dispose of hazardous materials, hazardous waste or "CERCLA waste materials", during the January 21, 1988 inspection, a large pit, filled with dark, oily-appearing materials (presumably generated by a current tenant) was observed.

17. The name, address, telephone number, title and occupation of the person answering this "Request for Information", who does not have personal knowledge of the answers is:

William K. Weddendorf
Manager, Corporate Hazardous Materials
Morton International, Inc.
110 North Wacker Drive
Chicago, IL 60606
(312) 807-2158

At the present time, no other person assisted in any manner, other than to provide clerical services, in responding to the "Request for Information":

CERTIFICATION OF ANSWERS TO REQUEST FOR INFORMATION

State of Illinois

County of Cook

I certify under penalty of law that I have personally examined and am familiar with the information submitted in this document (response to EPA Request for Information) and all documents submitted herewith, and that based on my inquiry of those individuals immediately responsible for obtaining the information, I believe that the submitted information is true, accurate, and complete, and that all documents submitted herewith are complete and authentic unless otherwise indicated. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment.

William K. Weddendorf
NAME (print or type)

Manager,
Corporate Hazardous Materials
TITLE (print or type)

W. K. Weddendorf
SIGNATURE

Sworn to before me this 23rd day
of February, 1990.

Notary Public

My commission expires March 24 1990

EXHIBIT NO 1

RESTATED CERTIFICATE OF INCORPORATION
Of
THIOKOL CORPORATION

(Originally incorporated on September 2, 1969 under the name of Morton-Norwich Products, Inc.)

FIRST: The name of the Corporation is Thiokol Corporation.

SECOND: The address of the Corporation's registered office in the State of Delaware is 1209 Orange Street in the City of Wilmington, County of New Castle. The name of the Corporation's registered agent at such address is The Corporation Trust Company.

THIRD: The purpose of the Corporation shall be to engage in any lawful act or activity for which corporations may be organized under the General Corporation Law of the State of Delaware.

FOURTH: The total number of shares of all classes of capital stock which the Corporation shall have authority to issue is 225,000,000 of which 25,000,000 shares shall be Preferred Stock of the par value of $1.00 per share and 200,000,000 shares shall be Common Stock of the par value of $1.00 per share.

Effective at 9:00 A.M. on the first business day following the date this Restated Certificate of Incorporation is filed with the Secretary of State of the State of Delaware, each five (5) shares of Common Stock, par value $1.00 per share, theretofore issued and then outstanding or held in the treasury shall be changed and combined into two (2) shares of validly issued, fully paid and nonassessable Common Stock, par value $1.00 per share, of the Corporation. No scrip or fractional shares will be issued by reason of this reverse split, and in lieu thereof the Corporation shall pay to each stockholder of record at the effective time an amount in cash based upon the average closing price of the Common Stock on the New York Stock Exchange for the five trading days beginning the date of the effective time, adjusted to reflect the change effected by this Restated Certificate of Incorporation and to exclude the distribution to the holders of Common Stock of one share of Morton International, Inc., an Indiana corporation, for each share of Common Stock of the Corporation held prior to the effective time.

A. *Preferred Stock.* In addition to a series of Preferred Stock designated as "Series A Junior Participating Preferred Stock," the terms of which are set forth below, the Board of Directors is expressly authorized to provide for the issue of all or any shares of the Preferred Stock, in one or more series, and to fix for each such series such voting powers, full or limited, or no voting powers, and such designations, preferences and relative, participating, optional or other special rights and such qualifications, limitations or restrictions thereof, as shall be stated and expressed in the resolution or resolutions adopted by the Board of Directors providing for the issue of such series (a "Preferred Stock Designation") and as may be permitted by the General Corporation Law of the State of Delaware. The number of authorized shares of Preferred Stock may be increased or decreased (but not below the number of shares thereof then outstanding) by the affirmative vote of the holders of a majority of the voting power of all of the then outstanding shares of the capital stock of the Corporation entitled to vote generally in the election of directors (the "Voting Stock"), voting together as a single class, without a separate vote of the holders of the Preferred Stock, or any series thereof, unless a vote of any such holders is required pursuant to any Preferred Stock Designation.

Series A Junior Participating Preferred Stock:

SECTION 1. *Designation and Amount.* The shares of such series shall be designated as "Series A Junior Participating Preferred Stock" (the "Series A Preferred Stock") and the number of shares constituting the Series A Preferred Stock shall be 600,000. Such number of shares may be increased or decreased by resolution of the Board of Directors; *provided*, that no decrease shall reduce the number

of shares of Series A Preferred Stock to a number less than the number of shares then outstanding plus the number of shares reserved for issuance upon the exercise of outstanding options, rights or warrants or upon the conversion of any outstanding securities issued by the Corporation convertible into Series A Preferred Stock.

SECTION 2. *Dividends and Distributions.*

(A) Subject to the rights of the holders of any shares of any series of Preferred Stock (or any similar stock) ranking prior and superior to the Series A Preferred Stock with respect to dividends, the holders of shares of Series A Preferred Stock, in preference to the holders of Common Stock, par value $1.00 per share (the "Common Stock"), of the Corporation, and of any other junior stock, shall be entitled to receive, when, as and if declared by the Board of Directors out of funds legally available for the purpose, quarterly dividends payable in cash on the second Monday of March, June, September and December in each year (each such date being referred to herein as a "Quarterly Dividend Payment Date"), commencing on the first Quarterly Dividend Payment Date after the first issuance of a share or fraction of a share of Series A Preferred Stock, in an amount per share (rounded to the nearest cent) equal to the greater of (a) $1 or (b) subject to the provision for adjustment hereinafter set forth, 100 times the aggregate per share amount of all cash dividends, and 100 times the aggregate per share amount (payable in kind) of all non-cash dividends or other distributions, other than a dividend payable in shares of Common Stock or a subdivision of the outstanding shares of Common Stock (by reclassification or otherwise), declared on the Common Stock since the immediately preceding Quarterly Dividend Payment Date or, with respect to the first Quarterly Dividend Payment Date, since the first issuance of any share or fraction of a share of Series A Preferred Stock. In the event the Corporation shall at any time declare or pay any dividend on the Common Stock payable in shares of Common Stock, or effect a subdivision or combination or consolidation of the outstanding shares of Common Stock (by reclassification or otherwise than by payment of a dividend in shares of Common Stock) into a greater or lesser number of shares of Common Stock, then in each such case the amount to which holders of shares of Series A Preferred Stock were entitled immediately prior to such event under clause (b) of the preceding sentence shall be adjusted by multiplying such amount by a fraction, the numerator of which is the number of shares of Common Stock outstanding immediately after such event and the denominator of which is the number of shares of Common Stock that were outstanding immediately prior to such event.

(B) The Corporation shall declare a dividend or distribution on the Series A Preferred Stock as provided in paragraph (A) of this Section immediately after it declares a dividend or distribution on the Common Stock (other than a dividend payable in shares of Common Stock); provided that, in the event no dividend or distribution shall have been declared on the Common Stock during the period between any Quarterly Dividend Payment Date and the next subsequent Quarterly Dividend Payment Date, a dividend of $1 per share on the Series A Preferred Stock shall nevertheless be payable on such subsequent Quarterly Dividend Payment Date.

(C) Dividends shall begin to accrue and be cumulative on outstanding shares of Series A Preferred Stock from the Quarterly Dividend Payment Date next preceding the date of issue of such shares, unless the date of issue of such shares is prior to the record date for the first Quarterly Dividend Payment Date, in which case dividends on such shares shall begin to accrue from the date of issue of such shares, or unless the date of issue is a Quarterly Dividend Payment Date or is a date after the record date for the determination of holders of shares of Series A Preferred Stock entitled to receive a quarterly dividend and before such Quarterly Dividend Payment Date, in either of which events such dividends shall begin to accrue and be cumulative from such Quarterly Dividend Payment Date. Accrued but unpaid dividends shall not bear interest. Dividends paid on the shares of Series A Preferred Stock in an amount less than the total amount of such dividends at the time accrued and payable on such shares shall be allocated pro rata on a share-by-share basis among all such shares at the time outstanding. The Board of Directors may fix a record date for the determination of holders of shares of Series A Preferred Stock entitled to

receive payment of a dividend or distribution declared thereon, which record date shall be not more than 60 days prior to the date fixed for the payment thereof.

SECTION 3. *Voting Rights.* The holders of shares of Series A Preferred Stock shall have the following voting rights:

(A) Subject to the provision for adjustment hereinafter set forth, each share of Series A Preferred Stock shall entitle the holder thereof to 100 votes on all matters submitted to a vote of the stockholders of the Corporation. In the event the Corporation shall at any time declare or pay any dividend on the Common Stock payable in shares of Common Stock, or effect a subdivision or combination or consolidation of the outstanding shares of Common Stock (by reclassification or otherwise than by payment of a dividend in shares of Common Stock) into a greater or lesser number of shares of Common Stock, then in each such case the number of votes per share to which holders of shares of Series A Preferred Stock were entitled immediately prior to such event shall be adjusted by multiplying such number by a fraction, the numerator of which is the number of shares of Common Stock outstanding immediately after such event and the denominator of which is the number of shares of Common Stock that were outstanding immediately prior to such event.

(B) Except as otherwise provided herein, in any other Certificate of Designations creating a series of Preferred Stock or any similar stock, or by law, the holders of shares of Series A Preferred Stock and the holders of shares of Common Stock and any other capital stock of the Corporation having general voting rights shall vote together as one class on all matters submitted to a vote of stockholders of the Corporation.

(C) Except as set forth herein, or as otherwise provided by law, holders of Series A Preferred Stock shall have no special voting rights and their consent shall not be required (except to the extent they are entitled to vote with holders of Common Stock as set forth herein) for taking any corporate action.

SECTION 4. *Certain Restrictions.*

(A) Whenever quarterly dividends or other dividends or distributions payable on the Series A Preferred Stock as provided in Section 2 are in arrears, thereafter and until all accrued and unpaid dividends and distributions, whether or not declared, on shares of Series A Preferred Stock outstanding shall have been paid in full, the Corporation shall not:

(i) declare or pay dividends, or make any other distributions, on any shares of stock ranking junior (either as to dividends or upon liquidation, dissolution or winding up) to the Series A Preferred Stock;

(ii) declare or pay dividends, or make any other distributions, on any shares of stock ranking on a parity (either as to dividends or upon liquidation, dissolution or winding up) with the Series A Preferred Stock, except dividends paid ratably on the Series A Preferred Stock and all such parity stock on which dividends are payable or in arrears in proportion to the total amounts to which the holders of all such shares are then entitled;

(iii) redeem or purchase or otherwise acquire for consideration shares of any stock ranking junior (either as to dividends or upon liquidation, dissolution or winding up) to the Series A Preferred Stock, provided that the Corporation may at any time redeem, purchase or otherwise acquire shares of any such junior stock in exchange for shares of any stock of the Corporation ranking junior (either as to dividends or upon dissolution, liquidation or winding up) to the Series A Preferred Stock; or

(iv) redeem or purchase or otherwise acquire for consideration any shares of Series A Preferred Stock, or any shares of stock ranking on a parity with the Series A Preferred Stock, except in accordance with a purchase offer made in writing or by publication (as determined by the Board of Directors) to all holders of such shares upon such terms as the Board of

Directors, after consideration of the respective annual dividend rates and other relative rights and preferences of the respective series and classes, shall determine in good faith will result in fair and equitable treatment among the respective series or classes.

(B) The Corporation shall not permit any subsidiary of the Corporation to purchase or otherwise acquire for consideration any shares of stock of the Corporation unless the Corporation could, under subparagraph (A) of this Section 4, purchase or otherwise acquire such shares at such time and in such manner.

SECTION 5. *Reacquired Shares.* Any shares of Series A Preferred Stock purchased or otherwise acquired by the Corporation in any manner whatsoever shall be retired and cancelled promptly after the acquisition thereof. All such shares shall upon their cancellation become authorized but unissued shares of Preferred Stock and may be reissued as part of a new series of Preferred Stock subject to the conditions and restrictions on issuance set forth herein, in the Restated Certificate of Incorporation, or in any other Certificate of Designations creating a series of Preferred Stock or any similar stock or as otherwise required by law.

SECTION 6. *Liquidation, Dissolution or Winding Up.* Upon any liquidation, dissolution or winding up of the Corporation, no distribution shall be made (1) to the holders of shares of stock ranking junior (either as to dividends or upon liquidation, dissolution or winding up) to the Series A Preferred Stock unless, prior thereto, the holders of shares of Series A Preferred Stock shall have received $100 per share, plus an amount equal to accrued and unpaid dividends and distributions thereon, whether or not declared, to the date of such payment, provided that the holders of shares of Series A Preferred Stock shall be entitled to receive an aggregate amount per share, subject to the provision for adjustment hereinafter set forth, equal to 100 times the aggregate amount to be distributed per share to holders of shares of Common Stock, or (2) to the holders of shares of stock ranking on a parity (either as to dividends or upon liquidation, dissolution or winding up) with the Series A Preferred Stock, except distributions made ratably on the Series A Preferred Stock and all such parity stock in proportion to the total amounts to which the holders of all such shares are entitled upon such liquidation, dissolution or winding up. In the event the Corporation shall at any time declare or pay any dividend on the Common Stock payable in shares of Common Stock, or effect a subdivision or combination or consolidation of the outstanding shares of Common Stock (by reclassification or otherwise than by payment of a dividend in shares of Common Stock) into a greater or lesser number of shares of Common Stock, then in each such case the aggregate amount to which holders of shares of Series A Preferred Stock were entitled immediately prior to such event under the proviso in clause (1) of the preceding sentence shall be adjusted by multiplying such amount by a fraction the numerator of which is the number of shares of Common Stock outstanding immediately after such event and the denominator of which is the number of shares of Common Stock that were outstanding immediately prior to such event.

SECTION 7. *Consolidation, Merger, etc.* In case the Corporation shall enter into any consolidation, merger, combination or other transaction in which the shares of Common Stock are exchanged for or changed into other stock or securities, cash and/or any other property, then in any such case each share of Series A Preferred Stock shall at the same time be similarly exchanged or changed into an amount per share, subject to the provision for adjustment hereinafter set forth, equal to 100 times the aggregate amount of stock, securities, cash and/or any other property (payable in kind), as the case may be, into which or for which each share of Common Stock is changed or exchanged. In the event the Corporation shall at any time declare or pay any dividend on the Common Stock payable in shares of Common Stock, or effect a subdivision or combination or consolidation of the outstanding shares of Common Stock (by reclassification or otherwise than by payment of a dividend in shares of Common Stock) into a greater or lesser number of shares of Common Stock, then in each such case the amount set forth in the preceding sentence with respect to the exchange or change of shares of Series A Preferred Stock shall be adjusted by multiplying such amount by a fraction, the numerator of which is the number of shares of Common Stock outstanding immediately after such event and the denominator

of which is the number of shares of Common Stock that were outstanding immediately prior to such event.

SECTION 8. *No Redemption.* The shares of Series A Preferred Stock shall not be redeemable.

SECTION 9. *Rank.* The Series A Preferred Stock shall rank, with respect to the payment of dividends and the distribution of assets, junior to all series of any other class of the Corporation's Preferred Stock.

SECTION 10. *Amendment.* The Certificate of Incorporation of the Corporation shall not be amended in any manner which would materially alter or change the powers, preferences or special rights of the Series A Preferred Stock so as to affect them adversely without the affirmative vote of the holders of at least two-thirds of the outstanding shares of Series A Preferred Stock, voting together as a single class.

B. *Common Stock.* Except as otherwise required by law or as otherwise provided in any Preferred Stock Designation, the holders of the Common Stock shall exclusively possess all voting power and each share of Common Stock shall have one vote.

FIFTH: A. *Number, election and terms of directors.* Subject to the rights of the holders of any series of Preferred Stock to elect additional directors under specified circumstances, the number of directors shall be fixed from time to time exclusively by the Board of Directors pursuant to a resolution adopted by a majority of the Whole Board (as defined in Article EIGHTH). Commencing with the 1989 annual meeting of stockholders of the Corporation, the directors, other than those who may be elected by the holders of any series of Preferred Stock under specified circumstances, shall be divided, with respect to the time for which they severally hold office, into three classes, with the term of office of the first class to expire at the 1990 annual meeting of stockholders, the term of office of the second class to expire at the 1991 annual meeting of stockholders and the term of office of the third class to expire at the 1992 annual meeting of stockholders, with each director to hold office until his or her successor shall have been duly elected and qualified. At each annual meeting of stockholders, commencing with the 1990 annual meeting, (i) directors elected to succeed those directors whose terms then expire shall be elected for a term of office to expire at the third succeeding annual meeting of stockholders after their election, with each director to hold office until his or her successor shall have been duly elected and qualified, and (ii) if authorized by a resolution of the Board of Directors, directors may be elected to fill any vacancy on the Board of Directors, regardless of how such vacancy shall have been created.

B. *Stockholder nomination of director candidates and introduction of business.* Advance notice of stockholder nominations for the election of directors and of business to be brought by stockholders before any meeting of the stockholders of the Corporation shall be given in the manner provided in the By-Laws of the Corporation.

C. *Newly created directorships and vacancies.* Subject to the rights of the holders of any series of Preferred Stock, and unless the Board of Directors otherwise determines, newly created directorships resulting from any increase in the authorized number of directors or any vacancies of the Board of Directors resulting from death, resignation, retirement, disqualification, removal from office or other cause shall be filled only by a majority vote of the directors then in office, though less than a quorum, and directors so chosen shall hold office for a term expiring at the annual meeting of stockholders at which the term of office of the class to which they have been elected expires and until such director's successor shall have been duly elected and qualified. No decrease in the numbers of authorized directors constituting the entire Board of Directors shall shorten the term of any incumbent director.

D. *Removal.* Subject to the rights of the holders of any series of Preferred Stock, any director, or the entire Board of Directors, may be removed from office at any time, but only for cause and only by the affirmative vote of the holders of at least 80 percent of the voting power of all of the then outstanding shares of the Voting Stock, voting together as a single class.

E. *Amendment, repeal or alteration.* Notwithstanding any other provisions of this Certificate of Incorporation or any provision of law which might otherwise permit a lesser vote or no vote, but in addition to any affirmative vote of the holders of any particular class or series of the capital stock required by law, this Restated Certificate of Incorporation or any Preferred Stock Designation, the affirmative vote of the holders of at least 80 percent of the voting power of all of the then-outstanding shares of the Voting Stock, voting together as a single class, shall be required to alter, amend or repeal this Article FIFTH.

SIXTH: In furtherance and not in limitation of the powers conferred by law, the Board of Directors is expressly authorized to make, alter, amend and repeal the By-Laws of the Corporation, subject to the power of the holders of the capital stock of the Corporation to alter, amend or repeal the By-Laws; *provided, however*, that, with respect to the powers of holders of capital stock to alter, amend and repeal By-Laws of the Corporation, notwithstanding any other provision of this Certificate of Incorporation or any provision of law which might otherwise permit a lesser vote or no vote, but in addition to any affirmative vote of the holders of any particular class or series of the capital stock of the Corporation required by law, this Restated Certificate of Incorporation or any Preferred Stock Designation, the affirmative vote of the holders of at least 80 percent of the voting power of all of the then-outstanding shares of the Voting Stock, voting together as a single class, shall be required to (i) alter, amend or repeal any provision of the By-Laws, or (ii) alter, amend or repeal any provision of this proviso to this Article SIXTH.

SEVENTH: Subject to the rights of the holders of any series of Preferred Stock, (A) any action required or permitted to be taken by the stockholders of the Corporation must be effected at an annual or special meeting of stockholders of the Corporation and may not be effected by any consent in writing by such stockholders and (B) special meetings of stockholders of the Corporation may be called only by the Chairman of the Board or by the Board of Directors pursuant to a resolution adopted by a majority of the Whole Board. Notwithstanding any other provisions of this Restated Certificate of Incorporation or any provision of law which might otherwise permit a lesser vote or no vote, but in addition to any affirmative vote of the holders of any particular class or series of the capital stock of the Corporation required by law, this Restated Certificate of Incorporation or any Preferred Stock Designation, the affirmative vote of the holders of at least 80 percent of the voting power of all of the then-outstanding shares of the Voting Stock, voting together as a single class, shall be required to alter, amend or repeal this Article SEVENTH.

EIGHTH: A. (1) In addition to any affirmative vote required by law, by this Restated Certificate of Incorporation or by any Preferred Stock Designation, and except as otherwise expressly provided in Section B of this Article EIGHTH:

(i) any merger or consolidation of the Corporation or any Subsidiary (as hereinafter defined) with (a) any Interested Stockholder (as hereinafter defined) or (b) any other corporation (whether or not itself an Interested Stockholder) which is, or after such merger or consolidation would be, an Affiliate (as hereinafter defined) of an Interested Stockholder; or

(ii) any sale, lease, exchange, mortgage, pledge, transfer or other disposition (in one transaction or a series of transactions) to or with any Interested Stockholder or any Affiliate of any Interested Stockholder of any assets of the Corporation or any Subsidiary having an aggregate Fair Market Value (as hereinafter defined) of $10 million or more; or

(iii) the issuance or transfer by the Corporation or any Subsidiary (in one transaction or a series of transactions) of any securities of the Corporation or any Subsidiary to any Interested Stockholder or any Affiliate of any Interested Stockholder in exchange for cash, securities or other property (or a combination thereof) having an aggregate Fair Market Value of $10 million or more; or

(iv) the adoption of any plan or proposal for the liquidation or dissolution of the Corporation proposed by or on behalf of any Interested Stockholder or any Affiliate of any Interested Stockholder; or

(v) any reclassification of securities (including any reverse stock split), or recapitalization of the Corporation, or any merger or consolidation of the Corporation with any of its Subsidiaries or any other transaction (whether or not with or into or otherwise involving any Interested Stockholder) which has the effect, directly or indirectly, of increasing the proportionate share of the outstanding shares of any class of equity or convertible securities of the Corporation or any Subsidiary which is Beneficially Owned (as hereinafter defined) by any Interested Stockholder or any Affiliate of any Interested Stockholder;

shall require the affirmative vote of the holders of at least 80 percent of the voting power of all of the then outstanding shares of the Voting Stock, voting together as a single class. Such affirmative vote shall be required notwithstanding any other provisions of this Restated Certificate of Incorporation or any provision of law or of any agreement with any national securities exchange or otherwise which might otherwise permit a lesser vote or no vote.

(2) The term "Business Combination" as used in this Article EIGHTH shall mean any transaction which is referred to in any one or more of subparagraphs (i) through (v) of paragraph (1) of this Section A.

B. The provisions of Section A of this Article EIGHTH shall not be applicable to any particular Business Combination, and such Business Combination shall require only such affirmative vote as is required by law, any other provision of this Restated Certificate of Incorporation and any Preferred Stock Designation, if, in the case of a Business Combination that does not involve any cash or other consideration being received by the stockholders of the Corporation, solely in their respective capacities as stockholders of the Corporation, the condition specified in the following paragraph (1) is met or, in the case of any other Business Combination, the conditions specified in either of the following paragraph (1) or paragraph (2) are met:

(1) The Business Combination shall have been approved by a majority of the Continuing Directors (as hereinafter defined); provided however, that this condition shall not be capable of satisfaction unless there are at least three Continuing Directors.

(2) All of the following conditions shall have been met:

(i) The consideration to be received by holders of shares of a particular class (or series) of outstanding capital stock (including Common Stock and other than Excluded Preferred Stock (as hereinafter defined)) shall be in cash or in the same form as the Interested Stockholder or any of its Affiliates has previously paid for shares of such class (or series) of capital stock. If the Interested Stockholder or any of its Affiliates have paid for shares of any class (or series) of capital stock with varying forms of consideration, the form of consideration to be received per share by holders of shares of such class (or series) of capital stock shall be either cash or the form used to acquire the largest number of shares of such class (or series) of capital stock previously acquired by the Interested Stockholder.

(ii) The aggregate amount of (x) the cash and (y) the Fair Market Value, as of the date (the "Consummation Date") of the consummation of the Business Combination, of the consideration other than cash to be received per share by holders of Common Stock in such Business Combination shall be at least equal to the higher of the following (in each case appropriately adjusted in the event of any stock dividend, stock split, combination or shares or similar event):

(a) (if applicable) the highest per share price (including any brokerage commissions, transfer taxes and soliciting dealers' fees) paid by the Interested Stockholder or any of its Affiliates for any shares of Common Stock acquired by them within the two-

year period immediately prior to the date of the first public announcement of the proposal of the Business Combination (the "Announcement Date") or in any transaction in which the Interested Stockholder became an Interested Stockholder, whichever is higher, *plus* interest compounded annually from the first date on which the Interested Stockholder became an Interested Stockholder (the "Determination Date") through the Consummation Date at the publicly announced base rate of interest of The First National Bank of Chicago (or such other major bank headquartered in the City of Chicago as may be selected by the Continuing Directors) from time to time in effect in the City of Chicago, *less* the aggregate amount of any cash dividends paid, and the Fair Market Value of any dividends paid in other than cash, on each share of Common Stock from the Determination Date through the Consummation Date in an amount up to but not exceeding the amount of interest so payable per share of Common Stock; and

(b) The Fair Market Value per share of Common Stock on the Announcement Date or the Determination Date, whichever is higher.

(iii) The aggregate amount of (x) the cash and (y) the Fair Market Value, as of the Consummation Date, of the consideration other than cash to be received per share by holders of shares of any class (or series), other than Common Stock or Excluded Preferred Stock, of outstanding capital stock shall be at least equal to the highest of the following (in each case appropriately adjusted in the event of any stock dividend, stock split, combination of shares or similar event), it being intended that the requirements of this paragraph (2)(iii) shall be required to be met with respect to every such class (or series) of outstanding capital stock whether or not the Interested Stockholder or any of its Affiliates has previously acquired any shares of a particular class (or series) of capital stock:

(a) (if applicable) the highest per share price (including any brokerage commissions, transfer taxes and soliciting dealers' fees) paid by the Interested Stockholder or any of its Affiliates for any shares of such class (or series) of capital stock acquired by them within the two-year period immediately prior to the Announcement Date or in any transaction in which it became an Interested Stockholder, whichever is higher, *plus* interest compounded annually from the Determination Date through the Consummation Date at the publicly announced base rate of interest of The First National Bank of Chicago (or such other major bank headquartered in the City of Chicago as may be selected by the Continuing Directors) from time to time in effect in the City of Chicago, *less* the aggregate amount of any cash dividends paid, and the Fair Market Value of any dividends paid in other than cash, on each share of such class (or series) of capital stock from the Determination Date through the Consummation Date in an amount up to but not exceeding the amount of interest so payable per share of such class (or series) of capital stock;

(b) the Fair Market Value per share of such class (or series) of capital stock on the Announcement Date or on the Determination Date, whichever is higher; and

(c) the highest preferential amount per share, if any, to which the holders of shares of such class (or series) of capital stock would be entitled in the event of any voluntary or involuntary liquidation, dissolution or winding up of the Corporation.

(iv) After such Interested Stockholder has become an Interested Stockholder and prior to the consummation of such Business Combination: (a) except as approved by a majority of the Continuing Directors, there shall have been no failure to declare and pay at the regular date therefor any full quarterly dividends (whether or not cumulative) on any outstanding Preferred Stock; (b) there shall have been (I) no reduction in the annual rate of dividends paid on the Common Stock (except as necessary to reflect any subdivision of the Common Stock), except as approved by a majority of the Continuing Directors, and (II) an increase in such annual rate of dividends as necessary to reflect any reclassification (including any

reverse stock split), recapitalization, reorganization or any similar transaction which has the effect of reducing the number of outstanding shares of the Common Stock, unless the failure so to increase such annual rate is approved by a majority of the Continuing Directors; and (c) neither such Interested Stockholder nor any of its Affiliates shall have become the beneficial owner of any additional shares of Voting Stock except as part of the transaction which results in such Interested Stockholder becoming an Interested Stockholder; provided, however, that no approval by Continuing Directors shall satisfy the requirements of this subparagraph (iv) unless at the time of such approval there are at least three Continuing Directors.

(v) After such Interested Stockholder has become an Interested Stockholder, such Interested Stockholder and any of its Affiliates shall not have received the benefit, directly or indirectly (except proportionately, solely in such Interested Stockholder's or Affiliate's capacity as a stockholder of the Corporation), of any loans, advances, guarantees, pledges or other financial assistance or any tax credits or other tax advantages provided by the Corporation, whether in anticipation of or in connection with such Business Combination or otherwise.

(vi) A proxy or information statement describing the proposed Business Combination and complying with the requirements of the Securities Exchange Act of 1934, as amended, and the rules and regulations thereunder (or any subsequent provisions replacing such Act, rules or regulations) shall be mailed to all stockholders of the Corporation at least 30 days prior to the consummation of such Business Combination (whether or not such proxy or information statement is required to be mailed pursuant to such Act or subsequent provisions).

(vii) Such Interested Stockholder shall have supplied the Corporation with such information as shall have been requested pursuant to Section E of this Article EIGHTH within the time period set forth therein.

C. For the purposes of this Article EIGHTH:

(1) A "person" means any individual, limited partnership, general partnership, corporation or other firm or entity.

(2) "Interested Stockholder" means any person (other than the Corporation or any Subsidiary) who or which:

(i) is the beneficial owner (as hereinafter defined), directly or indirectly, of ten percent or more of the voting power of the outstanding Voting Stock; or

(ii) is an Affiliate or an Associate of the Corporation and at any time within the two-year period immediately prior to the date in question was the beneficial owner, directly or indirectly, of ten percent or more of the voting power of the then outstanding Voting Stock; or

(iii) is an assignee of or has otherwise succeeded to any shares of Voting Stock which were at any time within the two-year period immediately prior to the date in question beneficially owned by any Interested Stockholder, if such assignment or succession shall have occurred in the course of a transaction or series of transactions not involving a public offering within the meaning of the Securities Act of 1933, as amended.

(3) A person shall be a "beneficial owner" of, or shall "Beneficially Own", any Voting Stock:

(i) which such person or any of its Affiliates or Associates (as hereinafter defined) beneficially owns, directly or indirectly within the meaning of Rule 13d-3 under the Securities Exchange Act of 1934, as in effect on May 1, 1989; or

(ii) which such person or any of its Affiliates or Associates has (a) the right to acquire (whether such right is exercisable immediately or only after the passage of time), pursuant to any agreement, arrangement or understanding or upon the exercise of conversion rights, exchange rights, warrants or options, or otherwise, or (b) the right to vote pursuant to any agreement, arrangement or understanding (but neither such person nor any such Affiliate or Associate shall be deemed to be the beneficial owner of any shares of Voting Stock solely by reason of a revocable proxy granted for a particular meeting of stockholders, pursuant to a public solicitation of proxies for such meeting, and with respect to which shares neither such person nor any such Affiliate or Associate is otherwise deemed the beneficial owner); or

(iii) which are beneficially owned, directly or indirectly, within the meaning of Rule 13d-3 under the Securities Exchange Act of 1934, as in effect on May 1, 1989, by any other person with which such person or any of its Affiliates or Associates has any agreement, arrangement or understanding for the purpose of acquiring, holding, voting (other than solely by reason of a revocable proxy as described in subparagraph (ii) of this paragraph (3)) or disposing of any shares of Voting Stock;

provided, however, that in the case of any employee stock ownership or similar plan of the Corporation or of any Subsidiary in which the beneficiaries thereof possess the right to vote any shares of Voting Stock held by such plan, no such plan nor any trustee with respect thereto (nor any Affiliate of such trustee), solely by reason of such capacity of such trustee, shall be deemed, for any purposes hereof, to beneficially own any shares of Voting Stock held under any such plan.

(4) For the purposes of determining whether a person is an Interested Stockholder pursuant to paragraph (2) of this Section C, the number of shares of Voting Stock deemed to be outstanding shall include shares deemed owned through application of paragraph (3) of this Section C but shall not include any other unissued shares of Voting Stock which may be issuable pursuant to any agreement, arrangement or understanding, or upon exercise of conversion rights, warrants or options, or otherwise.

(5) "Affiliate" or "Associate" shall have the respective meanings ascribed to such terms in Rule 12b-2 of the General Rules and Regulations under the Securities Exchange Act of 1934, as in effect on May 1, 1989.

(6) "Subsidiary" means any corporation of which a majority of any class of equity security is owned, directly or indirectly, by the Corporation; *provided, however*, that for the purposes of the definition of Interested Stockholder set forth in paragraph (2) of this Section C, the term "Subsidiary" shall mean only a corporation of which a majority of each class of equity security is owned, directly or indirectly, by the Corporation.

(7) "Continuing Director" means any member of the Board of Directors of the Corporation who is unaffiliated with the Interested Stockholder and was a member of the Board prior to the time that the Interested Stockholder became an Interested Stockholder, and any director who is thereafter chosen to fill any vacancy on the Board of Directors or who is elected and who, in either event, is unaffiliated with the Interested Stockholder and in connection with his or her initial assumption of office is recommended for appointment or election by a majority of Continuing Directors then on the Board.

(8) "Fair Market Value" means: (i) in the case of stock, the highest closing sale price during the 30-day period immediately preceding the date in question of a share of such stock on the Composite Tape for New York Stock Exchange-Listed Stocks, or, if such stock is not quoted on the Composite Tape, on the New York Stock Exchange, or, if such stock is not listed on such Exchange, on the principal United States securities exchange registered under the Securities Exchange Act of 1934 on which such stock is listed, or, if such stock is not listed on any such exchange, the highest closing bid quotation with respect to a share of such stock during the 30-day period preceding the date in question on the National Association of Securities Dealers, Inc.

Automated Quotations System or any system then in use, or if no such quotations are available, the fair market value on the date in question of a share of such stock as determined by the Board in accordance with Section D of this Article EIGHTH; and (ii) in the case of property other than cash or stock, the fair market value of such property on the date in question as determined by the Board in accordance with Section D of this Article EIGHTH.

(9) In the event of any Business Combination in which the Corporation survives, the phrase "consideration other than cash to be received" as used in paragraphs (2)(ii) and (2)(iii) of Section B of this Article EIGHTH shall include the shares of Common Stock and/or the shares of any other class (or series) of outstanding capital stock retained by the holders of such shares.

(10) "Whole Board" means the total number of directors which this Corporation would have if there were no vacancies.

(11) "Excluded Preferred Stock" means any series of Preferred Stock with respect to which the Preferred Stock Designation creating such series expressly provides that the provisions of this Article EIGHTH shall not apply.

D. A majority of the Whole Board, but only if a majority of the Whole Board shall then consist of Continuing Directors or, if a majority of the Whole Board shall not then consist of Continuing Directors, a majority of the then Continuing Directors, shall have the power and duty to determine, on the basis of information known to them after reasonable inquiry, all facts necessary to determine compliance with this Article EIGHTH, including, without limitation, (i) whether a person is an Interested Stockholder, (ii) the number of shares of Voting Stock beneficially owned by any person, (iii) whether a person is an Affiliate or Associate of another, (iv) whether the applicable conditions set forth in paragraph (2) of Section B have been met with respect to any Business Combination, (v) the Fair Market Value of stock or other property in accordance with paragraph (8) of Section C of this Article EIGHTH, and (vi) whether the assets which are the subject of any Business Combination referred to in paragraph (1)(ii) of Section A have, or the consideration to be received for the issuance or transfer of securities by the Corporation or any Subsidiary in any Business Combination referred to in paragraph (1)(iii) of Section A has, an aggregate Fair Market Value of $10 million or more.

E. A majority of the Whole Board shall have the right to demand, but only if a majority of the Whole Board shall then consist of Continuing Directors, or, if a majority of the Whole Board shall not then consist of Continuing Directors, a majority of the then Continuing Directors shall have the right to demand, that any person who it is reasonably believed is an Interested Stockholder (or holds of record shares of Voting Stock Beneficially Owned by any Interested Stockholder) supply the Corporation with complete information as to (i) the record owner(s) of all shares Beneficially Owned by such person who it is reasonably believed is an Interested Stockholder, (ii) the number of, and class or series of, shares Beneficially Owned by such person who it is reasonably believed is an Interested Stockholder and held of record by each such record owner and the number(s) of the stock certificate(s) evidencing such shares, and (iii) any other factual matter relating to the applicability or effect of this Article EIGHTH, as may be reasonably requested of such person, and such person shall furnish such information within 10 days after receipt of such demand.

F. Nothing contained in this Article EIGHTH shall be construed to relieve any Interested Stockholder from any fiduciary obligation imposed by law.

G. Notwithstanding any other provisions of this Restated Certificate of Incorporation or any provision of law which might otherwise permit a lesser vote or no vote, but in addition to any affirmative vote of the holders of any particular class or series of the Voting Stock required by law, this Certificate of Incorporation or any Preferred Stock Designation, the affirmative vote of the holders of at least 80 percent of the voting power of all of the then-outstanding shares of the Voting Stock, voting together as a single class, shall be required to alter, amend or repeal this Article EIGHTH.

NINTH: A. A director of the Corporation shall not be personally liable to the Corporation or its stockholders for monetary damages for breach of fiduciary duty as a director, except for liability (i) for

any breach of the director's duty of loyalty to the Corporation or its stockholders, (ii) for acts or omissions not in good faith or which involve intentional misconduct or a knowing violation of law, (iii) under Section 174 of the General Corporation Law of the State of Delaware, or (iv) for any transaction from which the director derived an improper personal benefit. If the General Corporation Law of the State of Delaware is amended to authorize corporate action further eliminating or limiting the personal liability of directors, then the liability of a director of the Corporation shall be eliminated or limited to the fullest extent permitted by the General Corporation Law of the State of Delaware, as so amended. Any repeal or modification of this Section A by the stockholders of the Corporation shall not adversely affect any right or protection of a director of the Corporation existing at the time of such repeal or modification.

B. (1) Each person who was or is made a party or is threatened to be made a party to or is involved in any action, suit, or proceeding, whether civil, criminal, administrative or investigative (hereinafter a "proceeding"), by reason of the fact that he or she or a person of whom he or she is the legal representative is or was a director, officer or employee of the Corporation or is or was serving at the request of the Corporation as a director, officer, employee or agent of another corporation or of a partnership, joint venture, trust or other enterprise, including service with respect to employee benefit plans, whether the basis of such proceeding is alleged action in an official capacity as a director, officer, employee or agent or in any other capacity while serving as a director, officer, employee or agent, shall be indemnified and held harmless by the Corporation to the fullest extent authorized by the General Corporation Law of the State of Delaware as the same exists or may hereafter be amended (but, in the case of any such amendment, only to the extent that such amendment permits the Corporation to provide broader indemnification rights than said law permitted the Corporation to provide prior to such amendment), against all expense, liability and loss (including attorneys' fees, judgments, fines, ERISA excise taxes or penalties and amounts paid or to be paid in settlement) reasonably incurred or suffered by such person in connection therewith and such indemnification shall continue as to a person who has ceased to be a director, officer, employee or agent and shall inure to the benefit of his or her heirs, executors and administrators; *provided*, however, that except as provided in paragraph (2) of this Section B with respect to proceedings seeking to enforce rights to indemnification, the Corporation shall indemnify any such person seeking indemnification in connection with a proceeding (or part thereof) initiated by such person only if such proceeding (or part thereof) was authorized by the Board of Directors of the Corporation. The right to indemnification conferred in this Section B shall be a contract right and shall include the right to be paid by the Corporation the expenses incurred in defending any such proceeding in advance of its final disposition; *provided, however*, that if the General Corporation Law of the State of Delaware requires, the payment of such expenses incurred by a director or officer in his or her capacity as a director or officer (and not in any other capacity in which service was or is rendered by such person while a director or officer, including, without limitation, service to an employee benefit plan) in advance of the final disposition of a proceeding, shall be made only upon delivery to the Corporation of an undertaking by or on behalf of such director or officer, to repay all amounts so advanced if it shall ultimately be determined that such director or officer is not entitled to be indemnified under this Section B or otherwise.

(2) If a claim under paragraph (1) of this Section B is not paid in full by the Corporation within thirty days after a written claim has been received by the Corporation, the claimant may at any time thereafter bring suit against the Corporation to recover the unpaid amount of the claim and, if successful in whole or in part, the claimant shall be entitled to be paid also the expense of prosecuting such claim. It shall be a defense to any such action (other than an action brought to enforce a claim for expenses incurred in defending any proceeding in advance of its final disposition where the required undertaking, if any is required, has been tendered to the Corporation) that the claimant has not met the standards of conduct which make it permissible under the General Corporation Law of the State of Delaware for the Corporation to indemnify the claimant for the amount claimed, but the burden of proving such defense shall be on the

Corporation. Neither the failure of the Corporation (including its Board of Directors, independent legal counsel or stockholders) to have made a determination prior to the commencement of such action that indemnification of the claimant is proper in the circumstances because he or she has met the applicable standard of conduct set forth in the General Corporation Law of the State of Delaware, nor an actual determination by the Corporation (including its Board of Directors, independent legal counsel or stockholders) that the claimant has not met such applicable standard of conduct, shall be a defense to the action or create a presumption that the claimant has not met the applicable standard of conduct.

(3) The right to indemnification and the payment of expenses incurred in defending a proceeding in advance of its final disposition conferred in this Section B shall not be exclusive of any other right which any person may have or hereafter acquire under any statute, provision of the certificate of incorporation, By-Law, agreement, vote of stockholders or disinterested directors or otherwise.

(4) The Corporation may maintain insurance, at its expense, to protect itself and any director, officer, employee or agent of the Corporation or another corporation, partnership, joint venture, trust or other enterprise against any expense, liability or loss, whether or not the Corporation would have the power to indemnify such person against such expense, liability or loss under the General Corporation Law of the State of Delaware.

(5) The Corporation may, to the extent authorized from time to time by the Board of Directors, grant rights to indemnification, and rights to be paid by the Corporation the expenses incurred in defending any proceeding in advance of its final disposition, to any agent of the Corporation to the fullest extent of the provisions of this Section B with respect to the indemnification and advancement of expenses of directors, officers and employees of the Corporation.

TENTH: In addition to any other considerations which the Board of Directors may lawfully take into account, in determining whether to take or to refrain from taking corporate action on any matter, including proposing any matter to the stockholders of the Corporation, the Board of Directors may take into account the long-term as well as short-term interests of the Corporation and its stockholders (including the possibility that these interests may be best served by the continued independence of the Corporation), the interests of creditors, customers, employees and other constituencies of the Corporation and its subsidiaries and the effect upon communities in which the Corporation and its subsidiaries do business.

ELEVENTH: In furtherance and not in limitation of the powers conferred by law or in this Restated Certificate of Incorporation, the Board of Directors (and any committee of the Board of Directors) is expressly authorized, to the extent permitted by law, to take such action or actions as the Board or such committee may determine to be reasonably necessary or desirable to (A) encourage any person (as defined in Article EIGHTH of this Restated Certificate of Incorporation) to enter into negotiations with the Board of Directors and management of the Corporation with respect to any transaction which may result in a change in control of the Corporation which is proposed or initiated by such person or (B) contest or oppose any such transaction which the Board of Directors or such committee determines to be unfair, abusive or otherwise undesirable with respect to the Corporation and its business, assets or properties or the stockholders of the Corporation, including, without limitation, the adoption of such plans or the issuance of such rights, options, capital stock, notes, debentures or other evidences of indebtedness or other securities of the Corporation, which rights, options, capital stock, notes, evidences of indebtedness and other securities (i) may be exchangeable for or convertible into cash or other securities on such terms and conditions as may be determined by the Board or such committee and (ii) may provide for the treatment of any holder or class of holders thereof designated by the Board of Directors or any such committee in respect of the terms, conditions, provisions and rights of such securities which is different from, and unequal to, the terms, conditions, provisions and rights applicable to all other holders thereof.

TWELFTH: The Corporation reserves the right to amend, alter, change or repeal any provision contained in this Restated Certificate of Incorporation, and any other provisions authorized by the laws of the State of Delaware at the time in force may be added or inserted, in the manner now or hereafter provided herein or by statute, and all rights, preferences and privileges of whatsoever nature conferred upon stockholders, directors or any other persons whomsoever by and pursuant to this Restated Certificate of Incorporation in its present form or as amended are granted subject to the rights reserved in this Article.

EXHIBIT NO. 2

REACTION MOTORS, INCORPORATED
From December 1941 through April 1958

Frank H. Winter*
Space Science and Exploration Department
National Air and Space Museum
Smithsonian Institution
Washington, D.C., U.S.A.

Frederick I. Ordway**
Alabama Space and Rocket Center
Tranquility Base
Huntsville, Alabama, U.S.A.

Abstract

The history of a pioneering American rocket propulsion enterprise is presented from its early beginning as the entrepreneural outgrowth of liquid propellant rocket experiments conducted by the American Rocket Society in the 1930s to its eventual acquisition by Thiokol in 1958. Among the projects covered are the 3000-pound thrust liquid oxygen-gasoline assisted takeoff unit for the World War II PBM-3C flying boat, the 350- and 620-pound thrust units for the Gorgon and Lark missiles, the four-chamber 6000-pound thrust powerplants for Air Force and Navy experimental aircraft, the 8000-pound engine for the MX-774, and the 20,000 pound engine for the Viking high-altitude research rocket. Later projects, typified by the XLR-99 engine for the X-15 extreme altitude experimental airplane and "rocket-on-rotor" experiments, are also summarized.

I. Corporate History

America's first enterprise devoted to the commercialization of the rocket engine was created more than 40 years ago in the small town of Pompton Plains, New Jersey. Named, appropriately, Reaction Motors, Inc., it came into being less than a fortnight after the United States entered World War II. Its four founders were rocket enthusiasts who for years had been intimately connected with the American Rocket Society. All were convinced of the military and business potential of the rocket in the expanding world conflict.

Their enthusiasm was bolstered by the fact that in 1940, two of their number, H. Franklin Pierce and John Shesta, had received a request from an English firm for help in the development of war rockets. Declining the offer, they and their colleagues Lovell Lawrence, Jr. and James H. Wyld began, during 1941, to explore ways of attracting the U.S. military to the potential of the liquid propellant rocket engine.

The four men figured that the best approach would be to demonstrate to the military the 100-pound thrust regeneratively cooled rocket motor, which had been developed and tested by Wyld for several years. The time was appropriate, for American Rocket Society testing had accelerated during the summer of 1941 at a site turned up by Lawrence near Wanaque, New Jersey. There, Wyld and his colleques repeatedly fired the 100-pound unit for up to 40 seconds duration.

Heartened by the success of the motor, Lawrence got in touch with Dr. George Lewis, then director of aeronautical research at the National Advisory Committee for Aeronautics (BuAer) in Washington. Soon, interest was aroused as the agency began studying the potential of the Wyld engine.

During this same period, Lawrence, Pierce, Shesta and Wyld were meeting to consider the idea of forming a company. The name Reaction Motors was put forward by Wyld, who envisaged it as a kind of General Motors of the rocket world. "The analogy was not very close," he later admitted, "as we had scarcely two nickels to rub together, and our plant consisted mostly of half of the upper floor of John Shesta's brother-in-law's garage in North Arlington, N.J., which was about as large as a rather spacious outhouse."[1]

The men persisted in their aim of obtaining support from BuAer; and, according to Wyld, "Within a few weeks [of earlier contact] Lawrence had succeeded in wrangling a visit [in November 1941] from a U.S. Navy representative to witness a test run of the regenerative motor--again in a hidden spot in the woods near Wanaque. It was a good run, and

*Historian.
**Consultant: formerly, Engineering Division, Reaction Motors, Inc., Denville, New Jersey, U.S.A.

he departed quite enthusiastic." The Japanese 7 December attack on Pearl Harbor in Hawaii occurred shortly afterward, followed almost immediately by RMI's first Navy contract. "Very soon," continued Wyld, "we were installed in our own shop and working like beavers on our first experimental motors for the Navy."[2]

The initial meeting of the new company's incorporators was held at 1000 hours on 16 December 1941 at 150 Broadway, in New York City. They were Harry B. Davis; Charles N. Caldwell, Jr.; and Wilson D. Smith. On the same day, the Certificate of Incorporation of the company was filed with the Secretary of State of New Jersey and two days later a certified copy was recorded in the office of the County Clerk, Hudson County, New Jersey. At the 16 December meeting, transfers of stock subscriptions took place from Davis, Caldwell and Smith to H.W. Reese, B.D. Lawrence, and Beverly Blizard, who were then nominated as company directors for the ensuing year.

At 1300 hours in the afternoon of the 16th, the just constituted Board of Directors met at 32 Broadway in New York. The first order of business was for the corporation to receive one liquid propellant rocket engine valued at $5,000 from Lovell Lawrence, Jr.; John Sheets; E. Franklin Pierce; and James H. Wyld. Stock transfers were then effected, followed by the resignations of Blizard, Reese, and B.D. Lawrence and their immediate replacement by Lovell Lawrence, Sheets, Pierce and Wyld. This done, a 15-minute recess was taken. Upon reconvening, officers were elected and treasurer Sheets was instructed to open an account in RMI's name at the Prospect Park National Bank and the North Jersey National Bank of Pompton Plains. Finally, the board authorized president Lawrence to enter into negotiations with the U.S. Navy Department "to sell to said department the Liquid Fuel Rocket Motor for $5,000.00 and to offer the services (without charge) of the company's engineer [Wyld] to install and instruct in the use of same; conditioned, however, that said Navy Department commission this Corporation to build a similar motor capable of a thrust reaction of 1,000lbs, for the sum of $20,000.00, delivery to be made within five (5) months of the signing of the contract..."[3]

According to Sheets, the Navy set down the following obligations to be fulfilled by Reaction Motors within 180 days:

1. Deliver the existing Wyld motor to the Navy
2. Develop and demonstrate a similar 100-lb. (45 kg.) thrust motor operating on aviation gasoline and liquid oxygen.
3. Develop a 1,000-lb (453 kg.) thrust motor using the same propellants.
4. Demonstrate repeated starts and throttling of the engine down to half thrust.[4]

They got the Wyld motor off to the Navy on schedule and received a welcome $5,000. "With this money," recalls Sheets, "we purchased a 1-ton truck, rented an old building and set up shop in Pompton Lakes, N.J. We assigned ourselves nominal salaries and went to work".[5]

Who were these men? What did they have in common? And what brought them together to work "like beavers" under marginal conditions on an only slightly understood technology?

First and foremost, they were amateur rocket experimenters who had been working together since the mid-1930s under the auspices of the American Rocket Society. Each was technically trained and had worked on engineering and related projects. And the four men shared an entrepreneural spirit.[6]

Lovell Lawrence, Jr., president, was a graduate of Montclair State College in New Jersey. Prior to RMI, he had worked for 7 years at the International Business Machines Corp. as assistant to the chief engineer, Radiotype Division. There, he designed and supervised the installation of automatic radio-writing equipment for the U.S. Government. Lawrence would remain with Reaction Motors until 1951.

E. Franklin Pierce served both as vice president and head of test engineering. As early as 1929, he had become interested in rockets and had constructed an engine propelled by alcohol and liquid oxygen. With no built-in igniter, it had to be fired up by a flaming torch at the end of a long stick! Prior to joining RMI, Pierce served 4 years in the U.S. Navy in the machine trades and later worked in a similar capacity with New York City's Interborough Rapid Transit subway system. He stayed with RMI until 1947, when he sold his stock and departed for California to run a citrus farm.

The positions of treasurer and director of research and engineering were occupied by John Sheets. A graduate and postgraduate of Columbia University and later a civil engineering instructor there, he resigned as chief engineer of the Z-Flex Piston Ring Corp. to join RMI. Sheets was a well-known designer and experimenter at the American Rocket Society. When the Great Depression threw him out of work, he said he was thankful--"my job was beginning to interfere with my real work," e.g., testing rockets with his ARS colleagues. He later became an RMI vice president, a ition he held until 1952 when he resigned. Early the following year, he also left the company's board of directors.[7]

James H. Wyld accomplished his undergraduate and postgraduate work at Princeton University. Before joining RMI as secretary and chief research engineer, he was a design engineer at the Rahm Instrument Corp. His 100-pound thrust, liquid oxygen-alcohol rocket motor was, in the inventor's words,

"the first American design to apply regenerative cooling to all parts of the motor." Wyld died on 3 December 1953 while on sick leave from the company. He was only 41 years of age. (He had recently been on year-long loan to Oak Ridge, Tennessee where he investigated the potential of nuclear fission to rocket propulsion.)[8]

During the ensuing years of growth, many other professionals would join the RMI ranks. On the engineering and scientific sides, among the better known were William P. Munger, top-flight turbopump designer and long-time chief engineer; project engineers M.E. "Bud" Parker, Edward Neu, Bernard Pearlman, Robertson L. Youngquist, Albert G. Thatcher, and Harry W.Burdett, Jr.; William R. Wright, Jr., patents engineer; Paul F. Winternitz, expert in physical chemistry and at one time or another director or research and of laboratories; Robert L. Wehrli, research physicist; and Harry B. Horne, chemical engineer and engineering manager. Joseph W. Mollek was RMI's top manufacturing expert, Warren P. Turner its applications engineering and contracts head; and Laurence P. Heath its government relations coordinator. On the financial and administrative side, Henry H. Michaels played a key role for many years.

To get their program under way, RMI's four founders quickly focused attention on meeting the requirements for the 1000-pound thrust rocket engine, which was to be employed by the Navy to assist large, heavily laden flying boats during ponderous takeoff runs--jet assisted takeoff or JATO as the procedure came to be known. Not very exciting, perhaps; but, as Lawrence later pointed out, "we had to hang our hat on something that would sound practical to the greatest doubting Thomas. The words rocket and missile had to be handled with great tenderness."

Hang their hat, or rather hats, they did!

The early RMI rocket motors were much like the regeneratively cooled unit Wyld had developed back in 1938. Tests and improvements registered during the first half of 1942 helped bring thrust ratings up, with the Navy-contracted 1000-pound level being reached by November. A full 3400 pounds of thrust was attained by May 1943 in response to a second Navy contract that called for at least 3000 pounds (see Part II). All the while, company personnel strength was increasing from the original 4 in 1941 to nearly 20 as 1942 came to a close.

Expanded responsibilities and increased personnel put pressure on office, shop and test facilities. Conditions were primitive, indeed. The North Arlington garage space occupied by the company measured only 40 by 20 feet and was partitioned. One section served for administration and drafting, the other as machine shop and laboratory. Looking back from the vantage point of 10 years, the founders felt that

> In view of the company's limited requirements, the plant was efficient. When one of the four officer-employees received the nucleus of an idea, he reduced it to a design in the office drafting room, then donned a set of overalls and machined and assembled the unit. When it was completed, he tested it by pointing the proper end out of the back door and firing it into the New Jersey countryside.[9]

That kind of operation sufficed during 1942, but by year's end it had become clear that some expansion was in order. Consequently, the following January the infant firm moved into a three-story frame building located in Pompton Plains. Owned by a Mrs. Mary Dunn, the 11,600 square foot structure had previously been a silver factory (it dated from the late 1800s) and later "The Silver Circle" night club. It occupied a site on Boulevard at Route 23, close to the Pompton Plains - Riverdale line.

Leslie Collins, an early RMI employee, recalls that the move into the stucco-exterior structure "...went off very smoothly and all hands were in there pitching. There were the President, Vice President, Treasurer, Secretary and Foreman [Collins himself] and all the other employees (three), wiring up machines, drilling holes in concrete, setting up the engineering department and stock room. By Monday, January 17, 1943, the new plant was all ready to go."[10]

In addition to the old silver factory, RMI took advantage of the 3½ acres around it to erect three stands. One was used for testing liquid propellant rocket motors with thrust ratings up to 1500 pounds operating on liquid oxygen oxidizer and both gasoline and alcohol fuels. The second tested multi-motor units typified by RMI's four-chamber, 6000-pound thrust aircraft engines. And the third was employed in resonating-type duct engine testing. The company also maintained their original stand at nearby Franklin Lakes to test motors operating on liquid oxygen and both alcohol and gasoline at thrust ratings up to 3000 pounds.

Reaction Motors' location in the town of Pompton Plains inevitably led to complaints; after all, rocket motors are not test-fired in silence. As one inquiring reporter observed, "From a window of its single building one could toss a rock to the limits of its crowded test area."

A petition was soon drawn up by a number of irate citizens alleging that vibrations and explosive detonations were causing much unease and stress in the area. Local committeeman Emmet Petrin is then reported to have stated that "It's pretty evident that Reaction [Motors] is hurting our town, and the other members of the committee, speaking unofficially,

agree they ought not to be in a residential area." A young Riverdale housewife lamented that "When those tests go off, I'm scared out of my wits, the baby cries and the house shivers. Reaction ought to go some place, far, far away." [11]

A week or so later, the Newark Evening News reported a protest by the Pequannock Township Committee in which it was stated that RMI may go "out of business or out to the Pacific." It went on to add that Pequannock residents had "prayed for the necessary relief" from Reaction's experiments, which "are damaging the properties and health of the signers [of a written protest to the township] and their families." It was further reported that police chief Walter Sweetman had served notice on the company that its application of August 23 to store explosives had been denied. (The licence was officially revoked by him on October 25.) [12]

The upshot of all this was a mid-1946 move to a secluded location at the U.S. Naval Ammunition Supply Depot at Lake Denmark, New Jersey close to Dover. The change was particularly advantageous for the company's test operations, which could now take place at the 25-acre site with acoustic shielding afforded by wooded hills. [13]

Two large buildings in the old ordinance battalion area at Lake Denmark housed RMI's engine design and model construction and production facilities. Smaller structures served for administration, security, and other supporting services. Testing took place in a remote area on a narrow dirt road between the Depot and Hibernia. That the company was pleased with its new location is attested by in its First Annual Report:

> The location in a natural "bowl" of surrounding hills insulated by thousands of acres of Government property acquired specifically for ammunition storage and testing provides one of the best areas on the Eastern seaboard for rocket engine testing, yet within easy distance of an ample supply of skilled labor and test fuels. Following the move to Lake Denmark the construction of substantial testing facilities was started on Navy property and today the company operates one of the largest and best equipped liquid rocket engine testing facilities in the country. As a safeguard for future testing requirements, the Company has acquired a parcel of 237 acres of land just north of the present Navy sponsored test area. [14]

Three years after moving from Pompton Plains to Lake Denmark, RMI shifted its administrative, personnel, finance and manufacturing functions 5 miles away to a location at Elm and Stickle Streets in Rockaway. The move was celebrated on Tuesday, 6 December 1949 when the new facilities were inspected by a distinguished group that included Undersecretary of the Navy Daniel A. Kimball; Rear Admiral Lloyd Harrison, BuAer assistant chief of design and engineering; Rear Admiral Calvin M. Bolster, BuAer's assistant chief for R&D; Commander Robert C. Truax of the Naval Aeronautic Rocket Laboratory; Air Force procurement head for the New York region, Brigadier General Arthur Thomas; Colonel J.W. Sessums, Jr., deputy chief of R&D at the Air Force Materiel Command at Wright Field; Laurence S. Rockefeller; and many others.

Six years later, on 7 October 1955, the company formally dedicated a new and expanded plant at Denville consisting of three main structures: one for engineering and research, one for administration, and one for manufacturing. Utility and plant services were housed in separate buildings. At the same time, Reaction Motors' test facilities at Lake Denmark were modernized and expanded.

Each of these moves reflected further company growth. By 1943, the number of employees exceeded 20, then reached 55 in 1945, 120 in mid-1946, and 473 in 1947. This growth put an acute strain on RMI finances: while the company was technically prospering, financially it was going down hill. After posting a profit of $643 during 1942 (its initial full year of operation), it earned nothing the next four. [15]

At the end of the first full post-World War II year--1946--the firm's net worth was minus $100,000. And in mid-1947, it owed creditors some $600,000. RMI's problem was simple: too many fixed price contracts had become unprofitable when development costs exceeded estimates.

Fortunately, at this critical time Laurence S. Rockefeller came to the rescue. After many months of study and negotiation with RMI officials, Navy officers, and banking executives, he agreed to invest in the company. Charles Watson Newhall, Jr., then of the Rockefeller staff, recalled how the association came about. [16]

It was during the 1947 summer that Newhall first became involved with RMI, whose officers had recently approached Laurance S. Rockefeller and the Chase National Bank through their own First National Bank of Paterson, New Jersey. Later, as RMI's plight worsened, the Navy contacted Rockefeller saying, in effect, that we have a little company out in New Jersey that is making important contributions to Navy and Air Force rocket programs and we are most anxious to keep it alive. How about taking another look? [17]

"This," according to Newhall, "was a summons which loyal Navy man Laurence could not ignore. Likewise, it was a 'far out' new field of technical endeavor which was of interest to his new venture capital activities. In this instance, 'profit' was

of secondary consideration—helping the defense effort and pursuing a new technical field were primary." Newhall says he never learned who made the call, but assumes it was "someone in Admiral 'Savvy' Harrison's contract group."[18]

Rockefeller put Newhall in charge of investigating RMI to see if an agreement could be made. Newhall worked closely with Lovell Lawrence, Jr., president; Robert Lawrence, accounting; and Jack Pethick, treasurer. Newhall discovered that as of 31 August 1947, there was a working capital deficit in excess of $250,000.

The agreement between Rockefeller and RMI was signed 10 days later; and, according to Newhall, involved the purchase of $200,000 principal amount of 3-year, 4-percent notes with detachable warrants for the purchase of common stock. In March of 1948, this was increased by $100,000. By December of that same year, Reaction Motors' financial condition had improved to the point that the company could increase its line of revolving credit with Chase and the Paterson banks from $315,000 to $600,000.

"As soon as the agreement was signed," recalls Newhall, "Laurence asked me to move out to R.M.I. and 'hold the fort' until they selected someone as general manager. For the next 6 weeks, I interviewed numerous candidates sent out by the "New York office"--also showed them the temporary facilities at Lake Denmark. One afternoon, Laurance called and said that he and "Mac" (J.S. McDonnell of McDonnell Aircraft Co.) would like to come out and see me. 'J.S.' had been working closely with Laurance to help him with R.M.I."

Newhall remembers their settling into his small office and announcing that they had made their selection of general manager, "and it was me. You could have knocked me over with a feather," he added, "since I didn't know I was under consideration. I was pleased because I had become very interested in the company and its people."[19]

With the fresh injection of capital, the financial health of Reaction Motors improved. Employment increased, new equipment was installed, and business forecasts became optimistic. "In its relatively short life of seven years," an RMI report boasted, "the company has demonstrated its capabilities as one of the prime sources of liquid rocket power plants and accessories for the Services." Examples of the company's first seven years' achievements were then listed; see Table 1.[20]

Company growth continued; and, by 1951, 642 employees were on the rolls. Meanwhile, in early 1950, Raymond W. Young, Jr. arrived as vice president of engineering following a career of 24 years at Wright Aeronautical Corp. (including 10 as chief engineer). In October 1951, he replaced Lovell Lawrence, Jr. as president. Three months later, Newhall reported to the New York Society of Security Analysts that Reaction Motors had earned about $1.25 a share on 109,000 common shares in 1951 and that sales for the year had reached some $4.5 million (up a million dollars from the previous year). In December 1952, he announced as $4 million expansion program for the 11-year old firm.

In late November 1953, slightly more than 6 years after the RMI-Rockefeller agreement was negotiated, the Mathieson Chemical Corp. bought 50 percent of RMI's outstanding stock and hence a controlling interest in the company. The following May, Olin Industries, Inc. and Mathieson merged into the Olin Mathieson Chemical Corp. The 1955 slate of officers reflected the changed control of the 14-year old RMI (Table 2).

All the time, Reaction Motors was growing. At the end of 1954, the work backlog reached more than $7.5 million and sales climbed to $4.7 million. The next year, sales exceeded 1954's backlog, which in turn had soared to over $9 million. Sales exceeded $16 million in 1956 and almost reached $24.5 million in 1957. Between 1955 and early 1958, the number of employees rose from 669 to 1,639.

RMI's activities were being closely watched by another expanding company, the Thiokol Chemical Corp. Founded in 1929 as the first commercial producer of synthetic rubber in the United States, it had moved into the solid propellant rocket field following World War II. Its 1957 sales approximated $30 million. A merger between Thiokol and Reaction Motors seemed appropriate to the directors of both companies as well as to Olin Mathieson and Rockefeller, who between them controlled more than two-thirds of the outstanding RMI stock.

A merger with Reaction Motors was proposed to Thiokol stockholders at a meeting in Trenton, New Jersey on 17 April 1958. They were advised that if the merger were to become effective, "approximately 200,000 [actually 198,000] additional shares of capital stock of Thiokol Chemical Corporation will be issued to the holders of outstanding stock of RMI." Moreover, the approval by holders of 66-2/3 percent of Thiokol's outstanding capital stock would be required to authorize the proposed merger. Thiokol stockholders were informed by president J. W. Crosby that "All of your Directors join me in recommending a vote FOR this proposal." Thiokol stockholders were enthusiastic, voting 777,191 shares for the coming merger and a mere 3,884 against.[21]

The merger plan dominated the regular meeting of Reaction Motors' board of directors held in Room 5600, 30 Rockefeller Plaza in New York City the morning of 24 January 1958. In attendance were directors William C. Foster, Myron B. Gordon, Hans A. Klagsbrunn, Randolph B. Marston, Henry E. Michaels, Jr., Harry A. Sosnoski, Harper Woodward, and Raymond W. Young. Also pre-

sent were Joseph W. Antonides, vice president and executive assistant to president Young; Alexander L. Keyes, secretary and counsel; and Stuart N. Scott of the firm Root Ballentine, Harlan, Bushby and Palmer.

Two documents were distributed at the meeting dated 24 January: (1) form of the agreement between Thiokol and RMI, and (2) form of letter agreement between Thiokol and RMI's two principal stockholders, Olin Mathieson and Laurence S. Rockefeller. It was unanimously resolved:

> that the proposed Agreement, dated January 24, 1958, between Thiokol Chemical Corporation and this Company, in the form submitted to this meeting, be and the same hereby is approved, and that the proper officers of this Company be and they hereby are authorized and directed to execute and deliver such Agreement to Thiokol Chemical Corporation, in the name and on behalf of the Company.

William C. Foster, chairman of RMI's board of directors and executive vice president of Olin Mathieson, announced the overwhelming Reaction Motors' stockholder response: 203,802 shares for the merger with Thiokol, 1,415 shares opposed. The two companies were officially merged at midnight, 30 April 1958, with RMI becoming the Reaction Motors Division of the Thiokol Chemical Corp. The final phase of Reaction Motors' history was about to begin.[22]

In the following three sections, we describe some of the principal projects on which Reaction Motors worked from the time of its formation in December 1941 to its demise as a corporate entity. Part II treats auxiliary and principal power for aircraft, the area of original RMI focus and the one that set the company on its path towards fame and at least modest fortune. Test and sounding rocket activities occupy Part III, and the miscellaneous applications of rocket power Part IV. Since this is an historical paper, we do not always attempt to convert thrust measurements into their metric equivalents.

II. AUXILIARY AND PRINCIPAL POWER FOR AIRCRAFT

JATO Developments

Since RMI initiated its business with the development of JATO (jet-assisted take-off) units, it is useful to sketch briefly the background of this important application of the rocket and how the company fit into that background.

The idea of the rocket as an auxiliary powerplant for airplanes certainly did not originate with RMI and was hardly a new concept. In fact, JATOs trace back to the 1880s when an Englishman T.J. Bennett attached gunpowder rockets to a 30-pound steam-propelled model airplane as its steam engine was not sufficient to propel the model alone.[23]

E.H. Bales of Ashcroft, British Columbia, Canada, took out U.S. Patent No. 1,003,411 on 19 September 1911 for a "Pyrotechnical Auxiliary Propelling Mechanism," perhaps the world's first JATO patent in which large skyrockets were attached to an aircraft. Other patents followed, such as one by A. Lepinte on 19 February 1924 (British Patent No. 229,670) for rockets attached between biplane aircraft struts for either retarding the descent of the machine or, when needed, accelerating it. In Russia, V.I. Dudakov and V.A. Konstantinov took out their own patent on 8 October 1928 for the "Construction of Rocket Engines for Powered Aircraft Flight," which in essence was also a JATO.[24]

These gentlemen may or may not have known of possibly the first bonafide, full-scale successful JATO flight made 8 August the following year when a Bremen Type Junkers W33 land plane fitted with floats took off from the Elbe River, near Dessau, Germany, using six powder rockets ignited rapidly in pairs. Although Junkers was convinced that it would one day be possible to use rocket-assist to lift the then-large load of 5000 kg, follow-up experiments did not come until much later. In any case, Dudakov and Konstantinov immediately continued their own researches for the Soviet Army-supported Gas Dynamics Laboratory. They made their own solid-fuel flights beginning in 1931, first with a U-1 light aircraft and later with TB-1 bombers. More importantly, they initiated liquid-fuel JATOs, a fact that was probably quite unknown outside the USSR.

Probably too, the sensationalized rocket-assisted glider flights financed or flown in 1928-1929 by the colorful German automobile manufacturer, Fritz von Opel, clearly established the feasibility of both pure rocket aircraft and rocket assisted take-off even if Dudakov, Konstantinov and the early JATO pioneers remained totally obscure. By the mid-1930s, the military services of several nations were undertaking JATO development in earnest. Besides the USSR, these countries were Germany, the United States, Japan, Great Britain, and Poland.[25]

U.S. developments are of particular concern in this paper and are thus briefly considered. The earliest American researches with JATOs were started by the U.S. Army Air Corps in 1938 as an outgrowth of the famous GALCIT (Guggenheim Aeronautical Laboratory of the California Institute of Technology) as discussed at length in earlier IAF papers by the late Dr. Frank J. Malina. From GALCIT came the formation of the Aerojet Engineering Corp. in 1942, which was created chiefly for the purpose of manufacturing JATOs commercially. The Jet Propulsion Laboratory, established in 1944 as an outgrowth of GALCIT, similarly undertook JATO development.[26]

Lou Arata, one of the first to be hired by Reaction Motors and an expert shopman, contends that while his company started out in the JATO business (as did Aerojet), it was always interested in multiple applications of rocket power.

Whatever the project, RMI's principal supporter and customer was the U.S. Navy. As seen in Part I, its Bureau of Aeronautics was solicited early in the potential development of James Wyld's regeneratively cooled rocket engine. Subsequently, late in 1941, Lt. C. Fink Fischer of the Bureau informed RMI's four founders of the Navy's prime interest in rockets at the time--the assisted take-off of heavily loaded seaplanes. Fischer became RMI's contracting officer for the Navy.

The Navy soon came to support not one but five liquid-fuel JATO projects simultaneously. These were Reaction Motors; Aerojet and GALCIT (later, JPL); a group headed by Dr. Robert H. Goddard, inventor of the liquid-fuel rocket; and the Navy's own research team headed by Lt. Commander Robert C. Truax. Truax, who like Wyld had his original rocket engines tested on the ARS' Proving Stand No. 2 in 1938, began his own Navy JATO work late in 1941. Goddard signed his joint Navy and Army Air Forces contracts about the same time, but moved his personnel and equipment to the Naval Engineering Experiment Station at Annapolis, Maryland, in July 1942.[19]

It is a curious fact that three of the Navy's simultaneous JATO development programs were partly conducted at the same location--Annapolis. There RMI was assigned a small building at Annapolis in late November 1943. As Truax relates, not only did the pressure of the Pacific war dictate the immediate need for JATOs but the Navy also "wanted to try as many different parameters and designs as possible for the greatest chance of success." This is confirmed by Lou Arata, who adds that rocketry was then a wide open field with so many variables that needed proving out "even more groups or experimenters would have been welcome." In fact, all three Annapolis groups offered different approaches; but the competing rocketeers were always friendly and almost invariably were helpful to each other.

Goddard noted in his diary for 15 September 1942: "Went with Lt. [C. Fink] and Mrs. Fischer to New Jersey, and saw the Reaction Motors setup. Had dinner with them and Lawrence and Sheets..." Arata remembers occasional visits from Goddard and Truax and that the former loaned a pump to RMI. Unfortunately, it was defective and leaked! Goddard's papers reflect a continued close association with RMI and Truax throughout his (Goddard's) Annapolis years, up to his death in 1945. On one or two occasions, Lawrence suggested a merger with Goddard, but without results.[20]

The principle difference in approach to Navy JATOs was the choice of propellants. Goddard had been a liquid oxygen and gasoline man ever since he started with liquids back in 1920. Truax, who had independently developed his own regeneratively cooled rocket engine in the late 1930s, began with compressed air and gasoline. In tests with gasoline and liquid oxygen, he initially encountered ignition and combustion problems; but, by 1942, a solution was found. One of his assistants, Ensign Ray C. Stiff, made the lucky discovery of an entirely new combination, nitric acid and aniline. They were perfect hypergolic propellants; the two ingredients ignited spontaneously, thereby obviating the need for an artificial means of ignition, and combustion was smooth. Another benefit hypergolics offered the military was that super cold liquid oxygen or other cryogenics did not have to be used. This greatly simplified engine preparation and storage. In modern parlance, the propellants were "storable" or "packaged" in that they could be kept at room temperature. Such hypergolics as nitric acid and aniline could also deliver greater total impulse because of their greater density. Despite the extreme corrosiveness of the acid, Truax comfortably made the shift and was shortly followed by Aerojet and Goddard, though Goddard still objected to both its corrosive tendencies and toxicity.

Nitric acid as an oxidizer is alleged to have been tried as early as 1930 by Friedrich Sander in Germany. In 1932-33 the American Harry Bull tested nitric acid and turpentine, a mixture found not to be particularly smooth (the acid reacts well with only certain hydrocarbons). The Germans secretly began to develop their own hypergolic mixtures from the late 1930s, culminating in projects like the Wasserfall and Taifun missiles by the middle of World War II. At Reaction Motors, this form of propellant was not investigated until the mid-1940s, when it was employed in the Navy's Gorgon II-A and Lark programs (see Part III).[21]

The original Project EES-3401 Navy BuAer-Reaction Motors contract sealed in early 1942 stipulated that the company deliver the existing Wyld regeneratively cooled liquid oxygen-alcohol motor. A similar 100-pound thrust motor burning liquid oxygen and gasoline was also to be demonstrated. The primary requirement was to develop a 1000-pound thrust motor fueled by the same propellants and then to demonstrate repeated starts. We recall from Part I that these tasks had to be completed within 180 days (in light of the serious war situation).

Reaction Motors' founders felt it best not to deviate from the basic gasoline-liquid oxygen combination. But the Wyld engine was only designed for the cooler burning liquid oxygen and alcohol. According to Sheets, "A replica of the original Wyld motor quickly burned out when tested with gasoline. This would never do. A complete redesign was necessary." Among other things,

the machined aluminum bar nozzle was substituted by a copper one. The motor, known to RMI as the Wyld Regeneratively-Cooled Rocket Motor Serial No. 2 and to Wyld himself as the M15-G-1, worked successfully on the new fuel. It is now on exhibit, along with the original Wyld engine, in the National Air and Space Museum in Washington, D.C.

From this unit evolved other small experimental engines, which were tested on the American Rocket Society's Test Stand No.2 (also on exhibit in the Museum). As the portable stand was largely designed by Shesta and fabricated in Pierce's basement shop, it was easily "borrowed" from the Society whose own rocket experimental activities had ceased after the bombing of Pearl Harbor. This test stand could static-fire rockets up to 200 pounds thrust.[30]

RMI's first permanent stand, anchored to a concrete slab at Franklin Lakes, had an initial capacity of over 1000 pounds thrust. An adjacent blockhouse, which still exists and is an official historic monument of the State of New Jersey, was built about 12 feet (3.7 m) away from the stand. A surviving hand-written RMI log book (whose notations began on 20 March 1943), coupled with Lou Arata's recollections, indicate that Wyld had much to do with designing and improving the RMI stand, which featured a moveable security shelter that was rolled right over the stand when it was not in use.

The Wyld Serial No. 2 engine (and several smaller test motors) proved that gasoline and liquid oxygen could adequately work in a regenerative system. This motor was run about 50 times from a few seconds to over 60 seconds. Even before this part of the Navy contract was fulfilled, progress was made with the 1000 pound thrust motor. Because of its much larger size, far greater heat was expected. Consequently, stainless steel was chosen for the nozzle rather than aluminum or copper. Drawing from his past experience with this material, Shesta designed a set of punches and dies. With these, plus a second-hand hydraulic press located by Lawrence, "very satisfactory nozzles" were formed.

Lawrence was also responsible for developing remotely-controlled throttling valves operated by small electric motors and gearwork. Wyld and Lawrence applied for U.S. Patent No. 2,479,888 on 6 July 1943 for their throttling system; a patent entitled "Controlling System for Reaction Motors," was not granted until 23 August 1949.[31]

Spark plug or squib igniters were often troublesome. In one test, the spark plug porcelain broke causing a spray of oxygen to escape from the hole. Ignition delays, improper pre-mixing of the propellants or non-ignitions were typical. But in any case, the 1000 pound engine worked satisfactorily and was delivered to the Navy on schedule. (The original engine, according to one story, blew up not long before the qualification test was made. A replacement was then built in record time.)

As it turned out, Arata was to solve the hit or miss igniter problem himself. By the time the 1000 pound motor was finished, as related in one early RMI promotional pamphlet, ten different types of motors had been produced ranging from 50 to more than 1000 pounds thrust. Arata says this may have only applied to functioning motors, for several test blanks were also made. The National Air and Space Museum has two of these early JATOs on exhibit, an M17G unit (1942) of 1300 pounds thrust and an M19G motor of 2000 pounds thrust.[32]

Soon after the delivery of the 2000 pound unit, the Navy decided that much larger ones were feasible. RMI's second Navy contract thus called for a 3000 pound motor meant for installation in a PBM-3C patrol bomber and test flown in accordance with detailed specifications. Shesta made an interesting innovation in the new engine. He fitted a multi-hole (40 or more) oxygen injector into the head plate. These holes were aligned concentrically with holes in the lower plate that fed the gasoline. "These nozzles," he reports, "protruded slightly past the lower plate, the annular space providing a clearance for a thin film of gasoline feed. As the oxygen emerged from the central hole, it spread out in a cone that intersected the annulus of fuel and provided good mixing."

Arata recalls that informality marked the early days at Reaction Motors, with the modifications of designs and techniques such as these worked out over lunches or coffee breaks at the nearby Triangle Grill. Usually," he remarked half facetiously

> we met there to discuss an explosion that had occured the day or morning before. We would all pool our heads together to figure out what went wrong, where the obstruction or the hot spot was. Then one of us would say, 'Why not try such-and-such?' Dan [a nickname for Lawrence] would respond. "Yeh, let's try it!" Then we would all get back and work like hell, sometimes until 9,10, or 11 at night. Sometimes John [Shesta] would also come around with a clipboard and just make up modifications on-the-spot.[33]

"Our greatest problem during those years," Arata continued, "was heat transfer. Of course, regeneratively-cooled systems were the only way to go; but, this did not mean that all the cooling problems were solved, especially for long-duration runs. There was sometimes a delay in ignition due to slow propellant flow, causing ill-timed starts and overheating or 'hot spots.'"

One answer, which was far from perfect, was Pierce's idea of making a corrugated winding or spiral out of a metal ribbon by running it through the loosened gear teeth of a lathe. The windings were placed between the cooling jacket and the liner for swirling the coolant fuel. The purpose was to slow down the circulation process so the motor would be better cooled, the fuel would be adequately pre-heated for better combustion, and the ignition delays would be overcome.

The trouble with this technique was that the ribbons were not always placed in the right positions. After some test runs, motors would be dismantled to learn the reason for complications. Often it was found that the ribbons jammed in the wrong place, blocking rather than assisting fuel flow. The ribbons sometimes shifted unknowingly during the course of manufacture. RMI engineers began, negatively, to dub them "wiggle rings." Perhaps at one of the Triangle Grill sessions a better solution was worked out, for later wires were placed in grooves around the cooling liner. By adjusting them at different angles and lengths, it was possible to control or regulate the rate of coolant flow.[34]

The completed 3000-pound motor weighed 75 pounds with auxiliaries (the nitrogen pressure bottle and other tanks). The chamber was about 6 inches (15 cm) diameter and 6 feet (1.8 m) high. One run (conducted on 6 May 1943, according to the RMI log book account in Wyld's handwriting) lasted about 24 seconds at high thrust; the reaction was measured by the recorder at about 3180 pounds. Wyld wrote: "Flame straight, not remarkably long but intensely hot--started a number of small fires in woods and scorched ground. Also burned corners off some nearby sandbags...Motor appears to be in excellent shape after run..."

In subsequent tests, the usual igniter problems were encountered; but, on 14 May 1943, a "very long run, probably over 1 min." was recorded. This became the standard duration of the engine.[35]

Soon after, another solution was found for the heating problem. After one test in which the head plate blew off "with a sharp report" because of excessive pressures, water was injected through a simple tee connection into the gasoline line. This seemed to rectify the problem. "After May 24 [1943]," wrote Sheets, "all our tests used water injection." By October, the first static tests were made with simulated PBM-3C aircraft boattails made of plywood and covered with corrugated metal. They were conducted at RMI's facility in New Jersey.

Finally, the time arrived for quick takeoff and landing flight trials. Captain William L. Gore of the U.S. Marine Corps served as the pilot on the first Reaction Motors JATO flight at Annapolis on 12 January 1944. (He was already a veteran of other such flights, having managed Goddard's JATO unit on a PBY aircraft beginning in September 1942.) By every account, these trials went well. Yet, for all their labors, the Navy never officially adopted any of Reaction Motors' JATO units.

What had gone wrong?

In a word, it was the company's choice of the liquid oxygen and gasoline propellants. Compared with the proven efficiency and, more importantly, the convenience of hypergolics used by Truax and Aerojet/JPL, oxygen and gasoline simply were not practical, especially for emergency military use because of the reasons cited earlier (procuring and storing liquid oxygen, etc.) In the end, Aerojet's high-performance, fully storable solid propellant units became the most successful militarily and commercially. At the conclusion of the PBM tests, reminisced Sheets, "we had definitely given up gasoline as a propellant and switched to alcohol, which we felt much better suited for rockets than gasoline."

Notwithstanding its JATO disappointment, Reaction Motors progressed in other areas. In the words of Rear Admiral Calvin M. Bolster, the company had "already demonstrated remarkable engineering skill in this infant field" of rocketry. The firm was already becoming engaged in other, non-JATO projects. One involved providing main, rather than assisted, propulsion for experimental aircraft.[36]

Principal Power for Aircraft---Rocket Planes

Ironically, while the hypergolic propellant (red-fuming) nitric acid and aniline possessed qualities which made it highly desireable for JATO applications, it also had very serious drawbacks which made it highly undesirable use as the primary source of rocket propulsion for aircraft. The advantages have already been cited above: no igniter device needed, no cryogenic storage required, etc. This meant quick-starting, easily storable and powerful JATOs. On the other hand, as Goddard most objected to, the acid fumes were highly toxic besides being corrosive. Pilots of rocket planes would have been exposed to the greatest risks due to these drawbacks, not to mention the chance of unplanned, instantaneous combustion. These qualities of the rocket propellant may have been to RMI's disadvantage when it came to JATOs but worked to RMI's favor regarding rocket aircraft.[37]

Following RMI's JATO phase, the company turned away from gasoline and liquid oxygen and began experimenting with the original James Wyld choice of liquid oxygen and alcohol since this combination was cooler and easier to handle in regeneratively-cooled engines. RMI also undertook hypergolic developments which were successfully employed in the Gorgon II-A and Lark missile programs. Aerojet continued its own hypergolic research and by 1944 was devel-

oping a 2,000 lb (907 kg) thrust acid and aniline engine called Rotojet. It was meant for the proposed Northrop XP-79 rocket-propelled flying wing interceptor for the Army Air Forces. Neither the aircraft nor the engine materialized but late in 1944 two transonic aircraft projects began to evolve. One was the Navy proposal of a ground-launched turbojet-powered craft, later designated the Douglas D-558 and made in turbojet, jet and rocket, and all-rocket powered versions. The other project was sponsored by the Army Air Forces and was an air-launched all-rocket powered aircraft which became known as the Bell XS-1 and later the X-1.[38]

In January, 1945, the Navy's Ships Installations Branch was requested to develop a rocket powerplant using liquid oxygen and gasoline for the D-558. "At that time," according to the 1946 GALCIT survey Jet Propulsion, "no data was available for specific powerplant requirements. Accordingly, Reaction Motors, Inc. of Pompton Plains, N.J., was requested to undertake the development program on a small size powerplant. This approach was taken in order to anticipate and solve problems as soon as possible in small scale and hence save time as well [as] expenditures of money and equipment associated with large-scale tests. Numerous problems in motor ignition and gas feed control were worked on in this manner during February, March and April of 1945. In the early part of May it was decided that the power plant should deliver between 4,500 pounds [2,040 kg] and 6,000 pounds [2,720 kg] thrust. Consequently, the total thrust was divided into four parts of 1,500 pounds [680 kg] thrust each. By this method, the fourth motor can be added or deleted as required and the complete powerplant can be operated at any one of the immediate stages." The overall rocket motor became famous as the 6000C4 (6,000 lbs of thrust from four chambers).[39]

"In cooperation with the Army Air Forces' program of transonic aircraft research," the GALCIT survey continues, "the Navy has arranged to release the first propulsive unit of the above design to the Bell Aircraft Corp." This is how the 6000C4 was started under a Navy contract yet first powered the Air Forces' sponsored Bell X-1. According to Harry W. Burdett, Jr., RMI's chief engineer on the 6000C4, the original engine's outer jacket was made of ordinary carbon steel (Shesta says this was chosen for reasons of economy). Carbon steel rusts. The engine also had copper tubing. Hence, when the Air Forces' Ezra Kotcher, head of their transonic aircraft project, came to Lovell Lawrence to examine the 6000C4 to see if it could indeed be used in the D-558 program, the engine was somewhat rusted and did not look presentable. Shesta recalls that the head of Bell's XS-1 design team, Robert M. Stanley, also saw the engine in this condition and said: "I don't like that. It's got to be stainless steel." The change was subsequently made and for better appearance sake the engine was also painted black. Burdett says that because of the tremendous noise plus its appearance, the 6000C4 was knicknamed the "Belching Black Bastard." However, he adds, this name had "to be cleaned up for the press." It was therefore re-dubbed "Black Betsy," after Lawrence's infant daughter, Betsy, and because the name also signified reliability. Officially, the Navy designation was the LR-8. The Air Forces designation was LR-11 (Liquid Rocket 11), or XLR-11-RM-1.[40]

Burdett says the first 6000C4 model was fired on 30 August 1945 but that only two of the chambers worked. The other two had fuel leaks. Blowouts and ignition and injection problems were common in the development of the engine, but Lou Arata, RMI's self-taught but expert shop man, devised a fool-proof igniter that was successfully tested 500 times without fail. In effect it was a miniature rocket in itself that was shaped like a Venturi with fuel and oxidizer inlet holes drilled in the sides. The fuel and oxidizer would be pre-mixed and ignited by an adjoining spark plug. Lawrence, who at that time had just returned from Germany after helping the U.S. Government investigate Germany's state-of-the-art of rocketry (i.e. just after the war), was so impressed with the igniter that he ordered Arata to immediately make four of them. The igniter was subsequently adapted to the 6000C4 according to Arata. Burdett says he himself was responsible for solving the injector problems. Prior to passing the qualification tests, the 6000C4 was test-fired in various positions for more than 800 seconds total as the unit could be placed horizontally as well as inclined up and down to 45 degrees. This movement of course simulated roll, pitch, and yaw in aircraft. Each of the chambers, which could be fired separately or in unison, were tested a minimum of 270 seconds. Once qualified, Betsy was accepted as RMI's Project No. 171, Contracts C-107193 and C-108792 to the Bell Aircraft Corp., effective 29 May 1946 with a scheduled completion date of 18 April 1947.[41]

The subsequent history of Reaction Motors 6000C-4-powered aircraft, the Bell XS-1 (X-1), also called "Glamorous Glennis," after the pilot's wife, is well covered in the literature. On 14 October 1947 the Bell X-1 with Captain Charles E. Yeager at the controls was the world's

first aircraft to fly faster than the speed of sound (Mach 1.06 or about 700 mph, 1,126 km/hr). Other data relative to this historic aircraft engine are that it burned an ethyl alcohol and water mixture with liquid oxygen. The welded, stainless steel and aluminum tubing engine was 54 inches (137 cm) long and 49 inches (124 cm) wide (the arrangement of the four thrust chamber tubes for the Air Forces' X-1 was in a diamond form; for the Navy's D-558 and other projects a square pattern was preferred). Each chamber was 18 inches (45 cm) in outside diameter. Total engine weight for the Bell X-1 version of the engine (nitrogen-fed type) was 345 lbs (156 kg) unfueled. Subsequent 6000C-4s under a trubopump feed system of 12.240 rpm's and driven by the decomposition of hydrogen peroxide.[42]

RMI's 6000C-4 also powered the Bell X-1A and Bell X-1-3 aircraft. With slight modifications, the engine was also fitted in the Navy's Douglas D-558-1 Skystreak which was also powered with an Allison J-35-A-11 5,000 lbs (2,268 kg) static thrust turbojet. Similarly, the Black Betsy was the powerplant for the all-rocket Douglas D-558-2 Skyrocket and the Douglas D-558-2 Skyrocket, jet and rocket version. Some of the D-558 series were modified for air-launches. These aircraft also flew supersonic. One of the planes, the Douglas D-558-2 #2 Skyrocket, jet and rocket version, became the world's first aircraft to exceed twice the speed of sound, reaching Mach 2.005 or 1,291 mph (2,077 km/hr) during a dive on 20 November 1953, Scott Crossfield pilot.[43]

The first rocket aircraft were purely experimental machines, however, designed to probe transonic flight. The Air Force's Republic XF-91, fitted with the 6000C-4, was the first supersonic combat fighter though technically it too was experimental. Like the Douglas Skyrocket, jet and rocket version, the XF-91 had dual powerplants. The rocket engine was considered an auxiliary means of propulsion for accelerated take-offs and climbs and for operations at high altitudes past the sonic barrier. The plane's General Electric J-47 turbojet of 5,200 lbs (2,358 kg) static thrust constituted the primary power. In the XF-91 the four rocket chambers were separated, two in a vertical line above the jet engine and two below. On an undisclosed date in September, 1952, Republic's Rusell (Rusty) Roth flew the XF-91 on the first of its supersonic flights. Republic's President, Mundy I. Peale, announced the flight shortly after, stressing that the XF-91 was "not purely a research plane" and "is combat ready." Only two of the aircraft were built, however, and no production contract was issued. A contemplated XF-91A unit with an up-rated 8000-pound thrust motor (possibly an Aerojet Engineering Co. development) designed for hypergolic propellants was never realized.[44]

This was not the end of Reaction Motors' rocket powerplants.

On 30 September 1955, a contract was let to the North American Aviation Co. for the development of a hypersonic rocket powered airplane designated by the Air Force the X-15. In their rocket and space travel history, Wernher von Braun and Frederick I. Ordway would later call the X-15 "the closest thing to a winged spacecraft that has ever been built" (up to 1966, when the first edition of their book was published; in fact, the X-15 represented a major step towards today's space shuttle).

Because of its experience and successes with earlier X-series airplanes, Reaction Motors was awarded the contract for the X-15 engine which, when later developed, became known as the fully throttable, 59,000-pound maximum thrust XLR99 "Pioneer." The unit operated on anhydrous ammonia and liquid oxygen propellants.

Early X-15 flights, made between 1959 and 1960, were accomplished with two modified "Black Betsy" engines with the Air Force designation XLR11.

As the subsequent development of the X-15 falls out of the time frame of this paper, it is not dealt with any further. It can, however, be noted herein that this remarkable airplane set a number of outstanding records. Among them: a 3 October 1967 flight that reached 4520 miles per hour (7274 km/hr) or Mach 6.7; and, on 22 August 1963, an altitude of 67 miles (107 km).[45]

Having made this observation, it is useful to note at this time that our paper does not include many minor Reaction Motors' activities nor, more especially, is it possible to deal with projects that may have got under way before the Thiokol Chemical Corp. takeover in 1958 but that would not mature until after that time within the framework of the Reaction Motors Division (RMI's successor designation).

III. TEST AND SOUNDING ROCKETS

Following a close second in importance to its aircraft auxiliary and principal rocket motors was a series of propulsion units for Navy and Air Force test and atmospheric sounding vehicles. Included were rocket motors developed and manufactured for the Lark surface-to-air flight test rocket, the MX-774 precursor to the Atlas intercontinental ballistic missile, and the Viking rocket used at first for extreme altitude exploration and later for testing components for the Vanguard satellite launch vehicle.

LR2-RM-12 and XLR6-RM-4 Engines for Lark

During 1944 and 1945, Reaction Motors build approximately fifty 350-pound thrust rocket engines that operated on mixed acid and mixed aniline hypergolic (self igniting) propellants. They were based on an earlier 340-pound CML-2N-1 U. S. Naval Engineering Experiment Station design and were mounted on the Gorgon II-A pilotless aircraft. The Navy planned on using these vehicles against Japanese naval and merchant shipping in the Pacific.

Building on CML-2N-1 experience, RMI engineers came up with a two-chamber unit consisting of 220 and 400-pound thrust chambers mounted together (the latter was an uprated Gorgon II-A cylinder). Two models evolved, the pressure-fed LR2-RM-12 and the turbopump-fed XLR6-RM-4. About 500 of these engines were built for the Lark ground and ship-to-air experimental missile. The idea was to use the smaller cylinder for cruising and the larger one for extra speed as the aerial target were approached. Data on the two engines are summarized in Table 3.

Manufactured both by the Fairchild Engine and Airframe Co. and the Consolidated Vultee Aircraft Corp., Lark was originally designated XSAM-N2a. Later, in 1950, it was reclassified as the CTV-N-9 component test vehicle. Most were fitted with Mach limiters that permitted the missile to reach but not to exceed Mach 0.85. When a Lark approached this speed, an indicator closed the electric valve which, in turn, closed the propellant valve and consequently stopped the operation of the 400-pound thrust chamber. The reverse occurred when the missile dropped below the limiting velocity. Launchings at first took place from a 450-foot (137 m) long inclined ramp at the Naval Ordnance Test Station, Inyokern, California. Later, they were made from a zero-length launcher at the Naval Air Missile Test Center in Point Mugu, also in California, as well as from the USS Norton Sound at sea. Typically, Lark would undergo 240 seconds of powered flight; but, during one test in December 1948, power lasted for 295 seconds carrying the missile over a distance of more than 25 miles (42.3 km).[46]

Although the 620-pound thrust engines were employed exclusively for Lark, the company felt they could be used as assist take-off units for light liaison and command-type aircraft. Lou Arata cannot recall any such use, though a 1946 GALCIT survey Jet Propulsion mentions an RMI motor in 1942 being converted to burn an unspecified fuel with nitric acid and making successful runs, "but then [it] exploded...and was abandoned." John Shesta believes that this motor may have been adapted by Lt. C. Fink Fischer at Annapolis to use the acid as acid tanks and other equipment were set up there.

XLR35-RM-1 Engine for MX-774

After the war, RMI carved out a small piece of the emerging large rocket-propelled missile programs that were based on or inspired by the German V-2 and other military vehicles. During the immediate postwar period, the Germans and their American colleagues were flying and testing captured V-2s from White Sands in New Mexico while simultaneously embarking on the new Hermes missile project. For its part, the Navy had started developing a Viking sounding rocket that was based in considerable part on V-2 technology. At the same time, the newly created Air Force was tackling a long-range, rocket-powered delivery vehicle using the MX-774 missile to test the concept.

As it turned out, RMI received engine development contracts for both the Air Force and Navy projects.

The MX-774 was short-lived, but did provide the Air Force; its airframe contractor, the Consolidated Vultee Aircraft Corp.; and Reaction Motors with valuable experience. The engine, designated XLR35-RM-1, had four-chambers, was regeneratively cooled, and was capable of operating over a nominal 7,600 to 8,400 pound thrust range. It consisted of a thrust assembly, a turbopump assembly, and associated components. The engine was flown three times in the 31¼-foot (9.6 m) long MX-774 test vehicle. In-flight pitch, roll and yaw control was accomplished by swivelling the four chambers, then a novel, untried method. The XLR35-RM-1 was the first engine to combine a turbopump feed system with variable thrust and multi-swivel, gyro-controlled chambers.

Design of the engine was completed in late 1946 and model and acceptance testing was undertaken in June of the following year. A maximum thrust of 8,800 pounds was obtained at a specific impulse of 227 seconds. General design specifications and operating characteristics are summarized in Table 4.

The MX-774's airframe was designed by a Convair team headed by Karel J. Bossart and consisted of three all-metal sections; the fuselage nose, fuselage center, and the tail. The nose was made of aluminum alloy and housed the electrical, stabilization, and guidance and control components and test instrumentation. The center consisted of propellant tankage constructed of welded aluminum. The liquid rocket engine and the

control surfaces were housed in the aluminum alloy structure in the tail section. Integral tanks were introduced to rocketry with the MX-774 and also the idea of separating the nosecone from the main rocket structure after peak altitude was realized.

The Reaction Motors rocket engine weighed 396 pounds (179.6 kg) and consumed liquid oxygen and alcohol. The decomposition products of hydrogen peroxide drove the turbine, which was coupled to two pumps that furnished the propellants to the combustion chambers.

The MX-774 was static-tested at Point Loma, San Diego, in California from mid-1947 to late 1948. As noted in Table 5, it was flown three times at the White Sands Proving Grounds in New Mexico in July, September and December. A failure in the electrical system led to premature cutoff of an otherwise flawlessly functioning first flight engine. MX-774 rose over a mile (1.7 km) high, then crashed only 600 feet (183 m) from the blockhouse. No. 2 fared somewhat better, reaching nearly 30 miles (48 km). Excessive oxygen tank pressure caused the missile to break apart in mid-air. The third flight went well for 15 seconds, when the engine cut off. An attempt was made to parachute-recover the missile, but vibrations caused it to explode. The MX-774 project is described in a number of sources. 47

XLR10-RM-2 Engine for Viking

The engine developed for the Naval Research Laboratory's RTV-N-12 Viking high-altitude sounding rocket was quite different from that selected for the MX-774. Instead of four small thrust chambers it relied on a single, large one that produced more than 20,000 pounds of thrust.

The contract to develop and manufacture the XLR10-RM-2 (the official designation of the Viking rocket engine) was signed in 1946 and the first powerplant was successfully test fired a year later. Although the early Viking launches were not impressive, in time the rocket exceeded the altitude capabilities of the captured German V-2s. Table 6 provides flight data for the missile from the first firing in May 1949 to the last in May 1957.

The engine consisted of a large combustion chamber, a turbopump unit, and associated valves and controls. All tankage, wiring and piping were supplied by the Glenn L. Martin Company prime contractor.

The initial operating characteristics and specifications of the engine are grouped in Table 7 . Over the years, improvements were made to the engine. Thus, it developed 20,450 pounds of thrust on the first Viking flight, 21,629 on the last.

The thrust cylinder consisted of the combustion chamber and a venturi nozzle. It was composed of a sheet nickel inner jacket rolled into a cylinder and welded. The engine was cooled by circulation of the alcohol fuel in an outer jacket surrounding the combustion chamber, supported approximately a quarter inch (0.63 cm) distant from the outside diameter of the chamber by spacer rods (that extended from one end of the chamber to the other in several short lengths). The outer jacket contour was interrupted by expansion channels which, when pressure was applied, tended to expand lengthwise to allow for thermal expansion of the combustion chamber in operation. A reinforcing ring was welded onto the jacket throat section to prevent the possible distortion of the nozzle throat. The fuel entered the engine by four 1¼-inch (5.7 cm) fittings at the nozzle end of the jacket and was distributed uniformly around the cylinder.

The power transmission and pumping units consisted of a single stage turbine and two centrifugal pumps. Hydrogen peroxide entered a gas generator containing a manganese dioxide catalyst. The resultant chemical reaction produced super heated steam, which was supplied to the turbine. The turbine operated at approximately 10,000 rpm, and developed an output of approximately 300 horse power. Impellers at both ends of the turbopump forced the propellants through the outlet ports of the pumps at the proper discharge pressures.

In its Viking application, the thrust chamber was mounted to a gimbal ring that permitted swiveling in a horizontal plane. Movement in the perpendicular plane was effected through a similar mounting of the gimbal ring to the missile airframe.

On 21 September 1948, a prototype engine produced 21,000 pounds of thrust for 66 seconds, a performance that satisfied NRL. The first production engine was shipped from RMI to the Glenn L. Martin Co. soon afterward. Viking No. 1, meanwhile, was taking shape there during the autumn, and by December it was completed. The next month, the sounding rocket was sent from Baltimore out to White Sands, New Mexico where it was readied for static and flight firing.

After a dry run on 28 February 1949, the first static test took place on 11 March, after several postponements. Steam from the turbine exhaust started a fire in the tail section's pipe insulation, but the rocket was not damaged. The second static test, on 28 April, was cut short prematurely when someone saw smoke, but no evidence of fire was found. Plans went ahead for the first launching.

It occurred on 3 May 1949 at 0900. Viking 1 reached an altitude of slightly over 50 miles (80.5 km), 163 seconds after takeoff--a highly creditable performance for the maiden flight of any rocket. It fell to Earth about 10 miles (16 km) from its launch point, having stayed aloft some 6 minutes. American high-altitude rocket

sounding was coming of age.

Since the experience of early flights was applied to the design of later models, no two Vikings were exactly alike. Flights 2 and 3, which took place in September 1949 and February 1950, reached approximately the same altitude as the first. Viking 4 was fired on 11 May 1950 from the USS Norton Sound in the Pacific. The test gave new information about the problems of launching rockets at sea and allowed scientists to gather data on the behavior of cosmic rays in the upper atmosphere at the geomagnetic equator. Despite the difficulties of a shipboard launch, the Project Reach rocket (as the operation was called) soared to a height of 106 miles (170.5 km), very nearly the theoretical maximum for that particular vehicle.

The next three flights were made from White Sands. Viking 5 reached an altitude of 108 miles (170.5 km) in November 1950. Then, the following month, Viking 6 reached only 4 miles (6.4 km) because of a rapid deterioration of aerodynamic stability after fin control was lost. Viking 7, flown in August 1951, established a record height of 136 miles (219 km). All three carried instruments that included Geiger counters, ionization chambers, photomultiplier tubes, and cameras.

More than a year went by before the next firing. The time was used to carry on design work, in process since 1950, for a larger, heavier Viking with a motor capable of firing for more than 100 seconds (compared to the 50 to 80 seconds of the earlier models). Almost all the extra 3500 pounds (1588 kg) that went into the new Vikings were propellant, not structure. The new sounding rocket could go higher than the old Vikings or carry heavier payloads to the same altitude.

Seven of the new Vikings and their rocket engines were built and flown. The only failure was the first one, Viking 8, which experienced one of the most unusual accidents in rocket history. During static testing on the morning of 6 June 1952, it broke loose from the test stand, flew 4 miles (6.4 km) up, and crashed on the desert 5 miles (8 km) away. Scientists and engineers on the scene could hardly believe their eyes as the rocket rose into the air. On future models, four tie-down points rather than two would be used and the rocket tail section strengthened.

The remaining six Vikings were fired between 15 December 1952 and 1 May 1957. Viking 11 distinguished itself in May 1954 by soaring to a new record height of 158 miles (254 km) with 852 pounds (386.5 kg) of instruments aboard. Its RMI rocket engine fired for 103 seconds and brought the vehicle up to a speed of 4300 miles (6923 km) per hour, also a record for the series.

Viking 12 was, in many ways, the last true member of the family. It reached a height of 144 miles (232 km) on 4 February 1955. The last two Vikings were fired, not for high-altitude research, but to check out components for the forthcoming Vanguard space carrier vehicle. They were flown from Cape Canaveral, Florida rather than White Sands.

Table 8 summarizes all 14 Viking flights.

The story of the Viking is well told in a number of sources, including a book and memoir paper by Milton Rosen who directed the rocket's development, and works by Homer E. Newell Jr. head of the Naval Research Laboratory's Rocket Sonde Research Section (later Branch). Looking back upon Viking from the perspective of several decades, Newell had this to say about the program:

> ...the Viking, although of a marvelous design...found very little use. The dozen rockets bought for the development program were, of course, instrumented for high-altitude research. But Viking was too expensive. The groups engaged in rocket sounding each had perhaps a few hundred thousand dollars a year to expend on the research, and a single Viking would have eaten up the whole budget...It had been hoped the Viking would be much less expensive, but before the end of the development these rockets became almost as expensive as new V-2s. So Viking found no takers among the atmospheric sounding groups and would probably have been shelved had it not been chosen as the starting point for the Vanguard IGY [International Geophysical Year] satellite launching vehicle.[48]

His assessment may not be entirely fair. True, Viking was an expensive vehicle. But it performed during its lifetime valuable research on the nature of upper atmospheric phenomena. Even more important, however much it may have owed to imported V-2 technology, Viking was an American project that provided vital experience to a growing cadre of native rocket scientists and technologists. This experience would prove its worth in the years to come--for Reaction Motors, for the Glenn L. Martin Co. and for its Navy sponsor.

IV. MISCELANEOUS PROJECTS

Throughout its life, RMI had proven its innovativeness. Apart from principal projects like JATOS and the famed 6000C-4, the firm also undertook several smaller but no less imaginative projects.

The RMI log book already mentioned reports a moment of inertia test on 1 May 1944 with a 60 pound (27 kg) Autogiro blade. According to Lou Arata, this was one of Franklin Pierce's projects. Sheets says the blade

came from Pitcairn Aviation Inc. The project was an attempt to test the feasibility of a liquid-propelled rocket-powered helicopter. For the purpose, says Arata, an A-frame was secured to a concrete slab. The rotating mechanism was affixed in the middle with a 2 inch (5 cm) diameter tube protruding from it. This tube simulated the blade for the actual combustion tests. Two 50 lb (22 kg) thrust liquid oxygen and gasoline rockets were strapped to each end of the tube, with fuel and oxidizer feed lines running down the tube towards the center where they were eventually connected to their respective tanks. The "blade" did work, after a fashion. It whirled as it should but Arata and Shesta say there was a great deal of leakage of liquid oxygen from the rotating rockets. Shesta adds that the "lox" evaporated and the feed was intermittent. The project was soon afterwards abandoned though it may have been the first attempt ever at liquid-propelled rocket-powered helicopters. The experiment also anticipated RMI's Rocket-On-Rotor (ROR) project of 1954.[49]

In July, 1944, Shesta says, "our engineers were summoned to the [Navy's] Bureau of Aeronautics in Washington for consultation in connection with the German V-1... At the same time, certain sketchy details of the construction of the powerplant were relayed to us and we were requested to construct and test a duplicate thereof. Work on this project was started in the middle of July and was completed on or about the first week in August, 1944. These tests continued to about the middle of September, 1944, at which time we took the motor to the Philadelphia Naval Aircraft Factory at Philadelphia, for further testing." The RMI log book reports one static test at the New Jersey plant on 15 September 1944. According to the log, the V-1 engine, which was recovered after it crashed in London, "Made 5 test starts without German reg. [ulator]...Ran as long as air was injected. Put in reg. made 3 test starts. #3 kept unit firing without air injection. After about 30 sec.[onds] the impulsing smoothed out and increased in intensity." The V-1 engine of course was an air-breathing pulsejet, not a rocket but it certainly fit the name and purpose of the company, a reaction motor. The 1946 GALCIT survey Jet Propulsion says RMI in fact "successfully modified the V-1's aeroresonator to extend the valve life to approximately four times that [of] the German valve." It was also noted that RMI "has practically completed development of an air-fuel intake system which will greatly reduce the drag of the propulsion device and increase the efficiency." Arata himself made a V-1 type engine "from the ground up." Some of the initial tests of the RMI model were interestingly done with smaller or scaled-down versions and also on a kind of wind tunnel made with an old aircraft engine for the purpose of ramming in air. Simulated air was also used and fed from tanks, consisting of 21% oxygen and 79% nitrogen. The Navy, concludes Shesta, were exploring the possibility of their own pulsejet missile. In fact, the pulsejet Loon did emerge but the motor was made by the Ford Motor Co.[50]

G. Edward Pendray, in his 1945 book The Coming Age of Rocket Power, mentions a rocket-driven boat tested by Pierce and other RMI officials during February and March of 1944 though there is no notation in the log book, which however, is incomplete. The potential of this device, according to Shesta, was to make a super-fast landing boat for use in the projected invasion of the Japanese islands. Pendray also mentions rocket boats for carrying mail ship-to-shore, rescue work and "for sport events." He also says standard RMI 250 lb (113 kg) thrust liquid oxygen and gasoline motors were used. Arata belived one of the Lark engines was used, possibly a 220 lb (100 kg) thrust unit though this employed nitric acid and aniline. As Shesta also recalls that the boat's motor "burned a very long time, about 5 minutes." It could well have been the Lark as it ran for 260 seconds (4.3 minutes), at least for the Lark's sustainer motor. In any case, Pierce made several experimental runs on the Severn River, near Annapolis, and reached speeds up to 40 mph (64 km/hr) with "no problem" but found steering extremely difficult especially with increased speeds.[51]

On a purely spare-time basis and "for fun only," RMI Chief Test Supervisor Ernest John "Buck" Pellington, a former World War II B-24 crew chief with 58 missions over Germany, supervised the design and construction of a stainless steel tubing rocket-propelled ice sled. Fitted with a 400 lb (180 kg) thrust liquid oxygen and alcohol engine, the 1,648 lb (747 kg), 16 foot (4.8 m) long sled attained a top speed of 90 mph (152 km/hr) in its initial test run on frozen Lake Hopatcong near the RMI plant at Dover, New Jersey. Pellington encountered rough ice and steering difficulties and had to shut off the motor after 18 seconds. Otherwise, greater speeds for the streamlined, aircraft-like

sled would have been possible. The Austrian Max Valier and the American Harry Bull made and rode rocket sleds in 1929 and 1931, respectively, but this was the first liquid propelled type.[52]

RMI became involved with another rocket-powered helicopter in 1951. The firm made the 16F1 hydrogen peroxide engines (16 lb or 7 kg thrust) for the tiny 100 lb (45 kg) two-bladed strap-on helicopter invented by Gilbert Magill. Magill manufactured the machine on an experimental basis under an Office of Naval Research contract through his Rotor-Craft Corp. of Glendale, Calif. The rockets were attached to each blade. The helicopter, known as the Rotorcraft RH-1 Project Pinwheel, was strapped to a man's back and waist with the man resting on a bicycle-style seat.. The military implications of Magill's invention were many and included soldiers leap-frogging over entire armies, climbing inaccessable terrains and so on. In effect, this was one of the first so-called "jet packs," though Magill's project seems to have been short-lived.[53]

A more bonafide helicopter was RMI's own ROR (Rocket-On-Rotor) produced in 1954, though preliminary work was begun in 1951. It consisted of small XLR32RM2 40 lb (18 kg) thrust hydrogen peroxide motors mounted on the three blade tips of an actual helicopter, the Sikorsky HRS-2 (S-55 type) of the U.S. Marine Corps. The system weighed 67 lbs (30 kg) dry yet could increase a helicopter's lifting potential by 20% which was a great boon in wartime situations. A dome-shaped tank above the rotor hub carried enough fuel for six minutes or 20-25 take-offs. Tests covered 1,000 starts and stops on helicopters of the Marine Experimental Squadron HMX-1 in Quantico, Virginia, with a 99.5% reliability record. Faster take-offs, higher altitudes, and improved rates of climb and hovering ceiling were also advantages of ROR, yet the system did not become operational.[54]

Apart from these miscellaneous projects, RMI was involved in many other, often very fruitful lines of research conducted during the period under consideration. Space permits only a small listing of some of them: with the establishment of RMI's Chemistry Laboratory in 1946 under Austrian-born chemical engineer Dr. Paul F. Winternitz, extensive research and experiments were conducted upon a variety of exotic propellants both solid and liquid, including diborane and other boranes, ethyleneoxide as a monopropellant, and liquid oxygen and ammonia; also, from 1946, the development of gas generators for airplane catapults using the rocket principle, under a Navy contract (also called Internal Combustion Catapult Powerplant or ICCP); rocket ramjet studies (from 1946); the X50-API Auxiliary Power Pack designed under an Air Force contract to produce auxiliary turbine power operating independently of the atmosphere (1950); solid propellant gas generator for tank pressurization (1951); avaluation of ceramics for thrust chambers, gas generators and igniters (1951); rockets for drilling in the ground (about 1951); boundry layer control air pumping systems for the Chase and Cessna Aircraft Companies (1952); turbo-rocket (1953 and earlier); Vernier rockets (1955); the development of a 500,000 lb (226,800 kg) thrust rocket system for an Air Force supersonic sled (1956); and many more.[55]

NOTES AND REFERENCES

1. From an unpublished five-page document by James H. Wyld, "A Biographical Sketch of the Rocket Career of James Wyld," in the RMI files, Thiokol Corp., Newtown, Mass., written c. 1951. The contract referred to was for $39,000 and was awarded by BuAer.

2. Wyld, "Biographical Sketch," op. cit.

3. From the Minutes of the First Meeting of Incorporators and the Minutes of the First Meeting of the Board of Directors, RMI files.

4. John Shesta, "Reaction Motors, Incorporated ---First Large Scale American Rocket Company: A Memoir," paper presented at the 29th IAF Congress, Dubrovnik, Yugoslavia, October 1978.

5. Ibid., Shesta reports the four men had but two small lathes, a drill press, an assortment of small tools and an oxy-acetelyne welding outfit.

6. At one time or another, all RMI founders had been or would be ARS presidents: Shesta, 1936; Pierce, 1940-41; Wyld, 1944-45; and Lawrence, 1946.

7. Shesta quote from Booton Herndon, "Rocket Genius with Big Ideas," Coronet, April 1953, p. 26.

8. James H. Wyld, "The Liquid Propellant Rocket Engine," Mechanical Engineering, June 1947, p. 5.

9. "Hobby Discussion Led to RMI Birth," The RMI Rocket, December 1951, p. 2.

10. RMI Rocket, op. cit., p. 6.

11. Quotes from John O. Davies, Jr., "Rocket Business Soars," Newark (N.J.) Evening News, 18 September 1946; and "Residents Cite Damage Done by Tests of Jet Propulsion," Newark Evening News, 2 October 1945, respectively.

12. "Pequannock Bans Jet Motors Testing," Newark Evening News, 10 October 1945.

13. Established in 1891 by Act of Congress, the Depot occupied a tract of land comprising 315 acres that had formerly been part of the United States Powder Depot (later to be known as Picatinny Arsenal). An additional 78 acres were purchased in 1902; and, in 1917 by Presidential Proclamation, 67 more were acquired. In 1948, the Naval Aeronautical Rocket Laboratory would be established on the site with the mission to develop and evaluate liquid propellant rocket engines and their components. On 1 April 1950, the Naval Ammunition Supply Depot's name would officially be changed to the Naval Air Rocket Test Station. Simultaneously, cognizance would be transferred from the Bureau of Ordnance to the Bureau of Aeronautics.

14. First Annual Report of Reaction Motors, Inc. for period ending 31 December 1948 (it covered the years 1947-1948).

15. This and related information was obtained by Ordway working with the RMI files located at the Thiokol Corp. headquarters in Newtown, Pa., during the course of discussions there with T. W. Brennan; William R. Wright, Jr., J. T. "Gus" Caton, and T. G. Tumelty on 15 February 1982; during interview with M.E. "Bud" Parker at Thiokol office in Huntsville, Alabama on 26 March 1982; and during interviews with John Sheets in Stowe and Laurance P. Heath in Morrisville, Vermont, 3-6 July 1982. Statistics are taken from RMI annual reports beginning with first that covered period ended 31 December 1948 and ending with the one covering the year 1957. (In 1958, Reaction Motors was absorbed by the Thiokol Chemical Corp.)

16. Personal communication to Ordway dated 3 April and 23 May 1982.

17. Laurence was the "gadgeteer" of the Rockefeller family and for years had been investigating in technology-oriented ventures. In the middle 1930s he had backed World War I ace Eddie Rickenbacker's fledgling Eastern Air Lines; and, in later years, moved into airplane design, electronics, and, with Reaction Motors, rocket engines. Cited by Joe Alex Morris in "The Rockefeller ..." The Saturday Evening Post, 13 January 1951, p. 116.

18. Newhall, loc. cit.

19. Newhall would remain as executive vice president to 1953 and general manager to 1951. In 1953, Rockefeller sent him to Flight Refueling, Inc.of Danbury,Conn., to study it as a possible RMI-Rockefeller joint investment. In January, they purchased a controlling interest in the firm from its British owner, Flight Refueling, Ltd. of Dorset. And in April, Newhall was made president and treasurer of Flight Refueling, Inc., which was relocated to new facilities in Baltimore, Md.

20. Section C-2(e), "History and Accomplishments," Report ANC-1062, 1948. RMI archives, Thiokol Corp., Newtown, Pa. (unpaginated).

21. Message to stockholders, Thiokol Chemical Corp., 17 March 1958 and Notice of Annual Meeting of Stockholders, 17 April 1958.

22. The story of the Reaction Motors Division of Thiokol will be covered by the authors in a separate paper.

23. T.J. Bennett, Letter, Flight, Vol. II, 26 March 1910, p. 244.

24. H.H. Bales, U.S. Patent 1,003,411 of 19 September 1911; A. Lepinte, British Patent 229,670 of 19 February 1924; V.I. Dudakov and V.A. Konstantinov, Russian Patent No. 439s of 8 October 1928, class 62s, I8/02 MPK V 64d.

25. I. Essers, Max Valier---A Pioneer Of Space Travel National Aeronautics and Space Administration: Washington, D.C., 1976, p. 189; V.I. Dudakov, "Analysis of the Early Period of Using JATO in Aviation," (in Russian), Proceedings of the 13th International Congress of the History of Science, Moscow, 18-24 August 1971, pp. 44-46; various documents in "JATO" file, National Air and Space Museum, Washington, D.C.

26. "JATO" file, op. cit.

27. Interview, Lou Arata, by Winter, 9 June 1982.

28. Interview, George S. James, by Winter, 8 June 1982; Interview, Robert C. Truax, by Winter, 7 June 1982; Esther C. Goddard and G. Edward Pendray, eds., The Papers of Robert H. Goddard (McGraw-Hill: N.Y., 1970), Vol. III, pp. 1478, 1558-1560, 1572-1573.

29. Interview, James, op. cit.; F.J. Malina, "The U.S. Army Air Corps Jet Propulsion Research Project, GALCIT Project No. 1, 1939-1946: A Memoir," in R. Cargill Hall, ed., Essays on the History of Rocketry and Astronautics: Proceedings of the Third Through the Sixth History Symposia of the International Academy of Astronautics (NASA Conference Publication 2014), Vol. II, pp. 167-168.

30. Shesta, "Reaction Motors," op. cit.; Interview, John Shesta, by Winter, 10 June 1982.

31. Interview, Arata, op. cit.; Reaction Motors, Inc., handwritten (pencil) logbook by James H. Wyld, Franklin Pierce, et. al., 1943-1945, donated to the National Air and Space Museum by John Shesta, unpaginated, hereafter cited as RMI Logbook; James H. Wyld and Lovell Lawrence, U.S. Patent No. 2,479,888 of 23 August 1949.

32. RMI Logbook, op. cit.; Interview, Arata, op. cit.

33. Shesta, "Reaction Motors," op. cit.; Arata Interview, op. cit.

34. Arata, Interview, op. cit.

35. Ibid; RMI Logbook.

36. RMI Logbook; Shesta, "Reaction," op. cit.; C.W. Schnare, "Development of ATO and Engines for Manned Rocket Aircraft," American Rocket Society Paper 2088-61, p. 9; Goddard and Pendray, op. cit., Vol. III, p. 1461; Interview, Shesta, op. cit.; Rear Admiral Calvin C. Bolster, The Assisted Take-Off of Air-Craft (Norwich University: Northfield, Vermont, 1950), p. 37.

37. Interview, James, op. cit.

38. Shesta, "Reaction," op. cit.; Interview, Shesta, op. cit.; Richard P. Hallion, Supersonic Flight (The McMillan Co.: N.Y., 1972), pp. 20-21, 39-40; Guggenheim Aeronautical Laboratory and The Jet Propulsion Laboratory, GALCIT, California Institute of Technology, [survey], Jet Propulsion (California Institute of Technology: [Pasadena, Calif.], 1946), pp. 136-137, hereafter cited as GALCIT survey.

39. GALCIT survey, op. cit.

40. Ibid; Interview, Harry W. Burdett, Jr., by Winter, 25 June 1982; Interview, Shesta, op. cit.; Interview, Arata, op. cit.; the account of the "Black Betsy" naming in Lloyd Mallan's Men, Rockets and Space Rats (Julian Messner: N.Y., 1958), p. 25 is not entirely accurate and is misleading.

41. Interview, Burdett, Jr., op. cit.; Interview, Arata, op. cit.; untitled Reaction Motors list of projects and project numbers, 1946-1955, in "Reaction Motors, Inc." file, National Air and Space Museum, unpaginated, hereafter cited as RMI List.

42. Hallion, op. cit., pp. 107-109, 202; Reaction Motors, Inc., Liquid Propellant Rocket Engines Developed For the U.S. Military Services, formerly a Confidential handbook, looseleaf, c. 1952, section on LR8-RM-6, hereafter cited as RMI Looseleaf Handbook; Interview, Burdett, Jr., op. cit.; some of these measurements were made by Winter directly from the 6000C-4 engine on exhibit in the National Air and Space Museum.

43. Hallion, op. cit., pp. 203-205, 172-173; RMI Looseleaf Handbook, passim.

44. "Rocket-Powered Fighter Breaks the Sound Barrier," New York Times, 10 December 1952; Albert M. Skea, "New Fighter Plane Fast," Newark Evening News, 10 December 1952; "Republic XF-91" file, National Air and Space Museum; Interview, Burdett Jr., op. cit.

45. Eugene M. Emme, ed., Aeronautics and Astronautics 1915-60 (U.S. Government Printing Office: Washington, D.C., 1961), p. 79; Wernher von Braun and Frederick I. Ordway, III, History of Rocketry & Space Travel (Thomas Y. Crowell Co.: N.Y., 1966), p. 204; "Progress with the X-15," Flight, Vol. 77, 27 May 1960, p. 732.

46. The Lark program got under way at the Bureau of Aeronautics in January 1945 and in December the first test article was delivered by Fairchild. During 1946, work was expanded to include the development of a guidance system for the vehicle. The pulse feature on the Lark was optional; most missiles were delivered with it, some without.

47. See for example, David Baker, The Rocket (Crown: N.Y., 1978), and Frederick I. Ordway, III and Ronald C. Wakeford, International Missile

and Spacecraft Guide (McGraw-Hill: N.Y., 1960).

48. Milton W. Rosen, The Viking Rocket Story (Harper and Brothers: N.Y., 1953) and Milton W. Rosen, "The Viking Rocket: A Memoir," paper presented at the 6th IAF History Symposium, Vienna, October 1972; Homer E. Newell, Jr., High Altitude Rocket Research (Academic Press: N.Y., 1954) and Homer E. Newell, Sounding Rockets (McGraw-Hill: N.Y., 1959); quote from Homer E. Newell, Beyond the Atmosphere (National Aeronautics and Space Administration: Washington, D.C., 1980), p. 58.

49. RMI Logbook, op. cit.; Interview, Lou Arata, op. cit.; Interview, Sherta, op. cit.

50. John Sherta, untitled document in Reaction Motors, Inc. archives at Thiokol Corp., Newtown, Pa.; RMI Logbook, op. cit.; GALCIT survey, p. 144; Interview, Arata, op. cit.

51. G. Edward Pendray, The Coming Age of Rocket Power (Harper & Brothers: N.Y., 1945), pp. 171-172; Interview, Arata, op. cit.; Interview, Sherta, op. cit.

52. "Rocket Propelled Boat Tested At Lake Hopatcong," Morristown Daily Record (N.J.), 3 March 1947; "Midvale Vet Hopes to Get Jet-Iceboat Up to 200 MPH," Midvale, N.J. paper, (unk.) March 1947.

53. RMI Looseleaf Handbook, section on 16F1 Rotor Rocket; "Tiny Rocket Helicopter Tested Here," Los Angeles, Cal. News, 29 October 1951.

54. RMI Looseleaf Handbook, op. cit., section on X96F3 Rotor Rocket; "Marines Visit RMI Employees, Show Off ROR," The RMI Rocket, Vol. 7, March 1956, pp. 1, 8; "Tiny New Rocket Engines Boost Payload For Copters," Aviation Week, 27 September 1954, p. 17; "Rocket Assistance For Helicopters," Flight, Vol. 66, 24 September 1954, p. 300.

55. RMI List, op. cit.; John D. Clark, Ignition! (Rutgers University Press: New Brunswick, N.J., 1972), passim; Memorandum from Paul F. Winternitz to R.M. Young, 19 December 1950 and other memos from the Lovell Lawrence papers, National Air and Space Museum.

Table I Achievements of Reaction Motors during First Seven Years

First American corporation dedicated solely to the development of liquid rocket engines and accessory equipment.

First development of regeneratively cooled liquid rocket engine generating 1000 pounds of thrust using liquid oxygen and alcohol propellants.

First regeneratively cooled liquid rocket engine generating 3000 pounds of thrust using liquid oxygen and gasoline propellants; powered first successful liquid rocket JATO unit in PBMC flying boat.

First rocket engine to propel a piloted aircraft faster than the speed of sound; Air Force XS-1. Many supersonic flights accomplished; impressive field record established by the four-chamber 6000-pound thrust engine.

First practical U.S.-developed turbine pump system for use with rocket engines. Basic design used with four engine models, ranging from 1500 pounds of thrust (in four-chamber 6000-pound thrust engine) to 20,000 pounds of thrust; driven by decomposing hydrogen peroxide in presence of catalyst.

First successful U.S.-developed turbine pump-driven power-plant for guided missile application; Air Force MX-774. — Unique thrust chamber swiveling feature to steer missile in its course successfully demonstrated.

First successful U.S.-developed turbine pump-driven rocket engine for piloted aircraft; Navy D558-2 then undergoing initial flight tests with 6000-pound thrust engine.

First development of 20,000-pound thrust, turbine-driven liquid oxygen-alcohol rocket engine for Navy's Viking high-altitude sounding rocket.

To development of 250-pound thrust acid-aniline rocket engines, tankage and controls; Navy Corvus missile program.

Development of 620-pound thrust, two-cylinder, acid-aniline engines for Navy Loki; several hundred delivered and flight tested.

Construction of fuel, oxidizer, and pressurizing service units for Loki engines.

First variable thrust, constant chamber pressure rocket engine; minimum thrust limit of 20 percent of rated 2,000 pounds.

Development of electronic and manual system for varying thrust by throttling of propellants.

First liquid rocket engine application to rotary wing craft; 50-pound thrust, liquid oxygen-alcohol thrust chambers used.

Investigations and tests on ramjet-type engines.

Application of rocket power to tools.

Research, development and testing of high-energy propellants, e.g. diborane and hydrazine as well as ammonia, turpentine, and furfuryl alcohol.

Development of tests for determining temperature of rocket jets by calculations and observations.

Investigations on use of liquid oxygen, white fuming nitric acid, JP4 and gasoline as propellants in systems of 5000 and 10,000 pounds of thrust, including thrust cylinders, propellant pumps, gas generators and controls.

Development of a complete line of accessories for rocket engines.

Development of special tools and equipment for constructing and checking rocket engine components and accessories.

Design, construction and operation of liquid rocket test areas, including test equipment and specialized instruments. Thrust capacity to 25,000 pounds (also at time contained also operating test cells with another fuel other constructions).

Table 2 Changing Directors and Officers at RMI 1949, 1952, 1955, 1958

1949

Directors

Lowell Lawrence, Jr., president, RMI
Randolph B. Marston, associate of Laurance S. Rockefeller, New York City
Charles W. Newhall, Jr., executive vice president and general manager, RMI
Stuart M. Scott, Root, Ballantine, Harlan, Bushby & Palmer, New York City (counsel)
John Sheets, director of research and engineering, RMI
Harper Woodward, associate of Laurance S. Rockefeller, New York City
James B. Wyld, chief research engineer, RMI

Executives and officers

Lowell Lawrence, Jr., president
Charles W. Newhall, Jr., executive vice president and general manager
Henry B. Michaels, Jr., vice president of finance and administration
John Sheets, director of research and engineering
Harry B. Horne, Jr., assistant to executive vice president and general manager and assistant secretary
Alexander L. Keyes, secretary and general counsel
John A. Pethick, treasurer
Joseph W. Mellak, Jr., manager of manufacturing
Laurence P. Heath, manager of contract administration and service
James B. Wyld, chief research engineer
Howard Helen, chief engineer
Dr. Paul Waterraitz, director of laboratories

1952

Directors

John A. Taylor, president, Aerovox Manufacturing Corp.
David L. Luke, Jr., president, West Virginia Pulp and Paper Co.
Randolph B. Marston (same as 1949)
Charles W. Newhall, Jr., executive vice president, RMI
Stuart M. Scott (same as 1949)
John Sheets, vice president, research, RMI
Harper Woodward (same as 1949)
James B. Wyld (same as 1949)

Executives and officers

Raymond W. Young, president and general manager
Charles W. Newhall, Jr., executive vice president
Henry B. Michaels, Jr., vice president and treasurer
John Sheets, vice president, research
Harry B. Horne, Jr., manager of engineering
Alexander L. Keyes (same as 1949)
William P. Munger, chief engineer
Dr. Paul Waterraitz, director of research

1955

Directors

Myron B. Gordon, aviation consultant, New York City
Russell Robinson, vice president for development, Olin Mathieson Chemical Corp.
Rose A. Klagsbrunn, Klagsbrunn, Lamas and Irwin, Washington, D.C.
Randolph B. Marston (same as 1949, 1952)
Henry B. Michaels, Jr., executive vice president, RMI
Walter P. O'Connell, vice president for finance, Olin Mathieson Chemical Corp.
Dr. Fred Olsen, vice president for research, Olin Mathieson Chemical Corp.
Harry A. Sosnoski, direct of operations, Aviation Division, Olin Mathieson Chemical Corp.
Harper Woodward (same as 1949, 1952)
Raymond W. Young, president, RMI

Executives and officers

Raymond W. Young, president
Henry B. Michaels, Jr., executive vice president
Robert S. Kinsey, vice president of operations
Alexander L. Keyes, secretary and counsel
James W. Fay, Jr., treasurer
William P. Munger, manager of engineering and research
David C. Eaton, works manager
Warren P. Turner, manager of customer relations and contracts
David G. Keller, manager of industrial and public relations
Robert M. Lawrence, assistant treasurer

1958

Directors

William C. Foster, chairman; senior vice president and director, Olin Mathieson Chemical Corp.
Myron B. Gordon (same as 1955)
L. Kermit Herndon, divisional vice president for research and production of the High Energy Fuels Division, Olin Mathieson Chemical Corp.
Rose A. Klagsbrunn (same as 1955)
Randolph B. Marston (same as 1949, 1952, 1955)
Henry B. Michaels, Jr., senior vice president and treasurer, RMI
Harry A. Sosnoski, divisional vice president for customer relations of the High Energy Fuels Division, Olin Mathieson Chemical Corp.
Harper Woodward (same as 1949, 1952, 1955)
Raymond W. Young (same as 1955)

Executives and officers

Raymond W. Young, president
Henry B. Michaels, Jr., senior vice president and treasurer
Joseph W. Antonides, vice president and executive assistant to the president
David C. Eaton, vice president for marketing
Fred B. Pfotenhauer, vice president for production
Alexander L. Keyes, secretary and counsel
Robert M. Lawrence, assistant treasurer and director of the finance division
Delacy F. Ferris, chief engineer
Edmund F. Perko, director of production division
Edward E. Seymour, director of research division
A. Robert Taylor, director of administration division

Table 3 LR2-RM-12 and XLR6-RM-4 General Design and Operating Characteristics

General	
Number of thrust chambers	2
Thrust chamber cooling	regenerative (oxidizer)
Electrical requirements, volts D.C.	24
Type of ignition	hypergolic
Propellants	
1. Fuel: monoethylaniline	62-66 percent composition by weight
aniline	24-28
diethylaniline	8-12
2. Oxidizer: nitric acid	81-85
sulphuric acid	14-17
water	4
nitrosylsulphuric acid	1 max.
water and nitrosylsuphuric acid combined	4.5 max.
Pressurizing gas	nitrogen or equivalent
Operating attitude	horizontal or vertical
Operating altitude	unrestricted (in air)
Design acceleration loads	18 g fore and aft; 10 g laterally
Operating temperature range, °F	20 to 120
Data Applicable Only to the LR2-RM-12	
Sea level thrust ratings, pounds	
1. Individual chambers	220-240; 390-410
2. Complete engine	610-650
Feed system	pressurized
Oxidizer manifold pressure, psig	460 ± 5
Fuel manifold pressure, psig	470 ± 5
Propellant control valve pressure, psig	400-500
Specific impulse at rated thrust, seconds	195
Specific propellant consumption, lb/sec/lb	0.00513
Data Applicable Only to the XLR6-RM-4	
Sea level thrust ratings, pounds	
1. Individual chambers	208-223; 374-401
2. Complete engine	582-624
Feed system	turbopump (blast turbine)
Propellant pressure at inlet to engine lines, psia	45 ± 2
Pump discharge pressure, psia	
1. Mixed acid	490
2. Monoethylaniline	420
Specific impulse at rated thrust, seconds	188
Specific propellant consumption, lb/sec/lb	0.00532

Table 4 XLR35-RM-1 General Design and Operating Characteristics

Number of thrust chambers	4
Sea level thrust ratings, pounds	
1. Individual chamber	2,050 ± 50
2. Complete engine	8,200 ± 200
Specific impulse at rated thrust, seconds	208
Specific propellant consumption, lb/sec/lb	0.00481
Thrust chamber cooling	regenerative (fuel)
Electrical requirements, volts D.C.	24
Type of ignition	power squib
Feed system	turbopump
Thrust to engine weight ratio	29
Propellants	
1. Fuel	ethyl alcohol
2. Oxidizer	liquid oxygen
3. Pressuring gas	nitrogen or equivalent
4. Pump drive	90% hydrogen peroxide
Flight load	20 g axial acceleration and/or 5 g lateral acceleration
Engine control pressure, psia	465 ± 10
Fuel feed pressure, psia	425 ± 5
Oxidizer feed pressure, psia	425 ± 5

Table 5 Flight Summary of the XLR35-RM-1-powered MX-774 Test Vehicle

Flight number	Date	Altitude, miles	Remarks
1	13 July '48	1.2	Premature cutoff at 12.6 seconds; stabilization satisfactory up to that time. Vehicle impacted after 48.5-second flight.
2	27 Sept.'48	29	Engine failed after 48 seconds at an altitude of 10 miles; maximum velocity: 1,700 miles per hour.
3.	2 Dec. '48	30	Premature burnout occurred at 51.7 seconds. Flight duration 294 seconds. Parachute deployment delayed, was torn loose from vehicle.

Table 6 XLR10-RM-2 General Design and Operating Characteristics

Number of thrust chambers	1
Sea level thrust rating, pounds	20,750
Specific impulse at rated thrust, seconds	195
Specific propellant consumption, lb/sec/lb	0.00513
Thrust chamber cooling	regenerative (by fuel)
Electrical requirements, volts D.C.	24
Type of ignition	pyrotechnic powder
Feed system	turbopump
Thrust to engine weight ratio	50.6
Propellants	
1. Fuel	95% ethyl alcohol, 5% water
2. Oxidizer	liquid oxygen
3. Pressurizing gas	nitrogen or equivalent
4. Pump drive	90% hydrogen peroxide
Maximum engine dry weight, pounds	222
Turbine shaft speed, rpm	10,000
Fuel inlet pressure, psia	35
Oxidizer inlet pressure, psia	45
Operating altitude	unrestricted
Operating attitude	unrestricted

Table 7 Flight Summary of the Viking Sounding Rocket

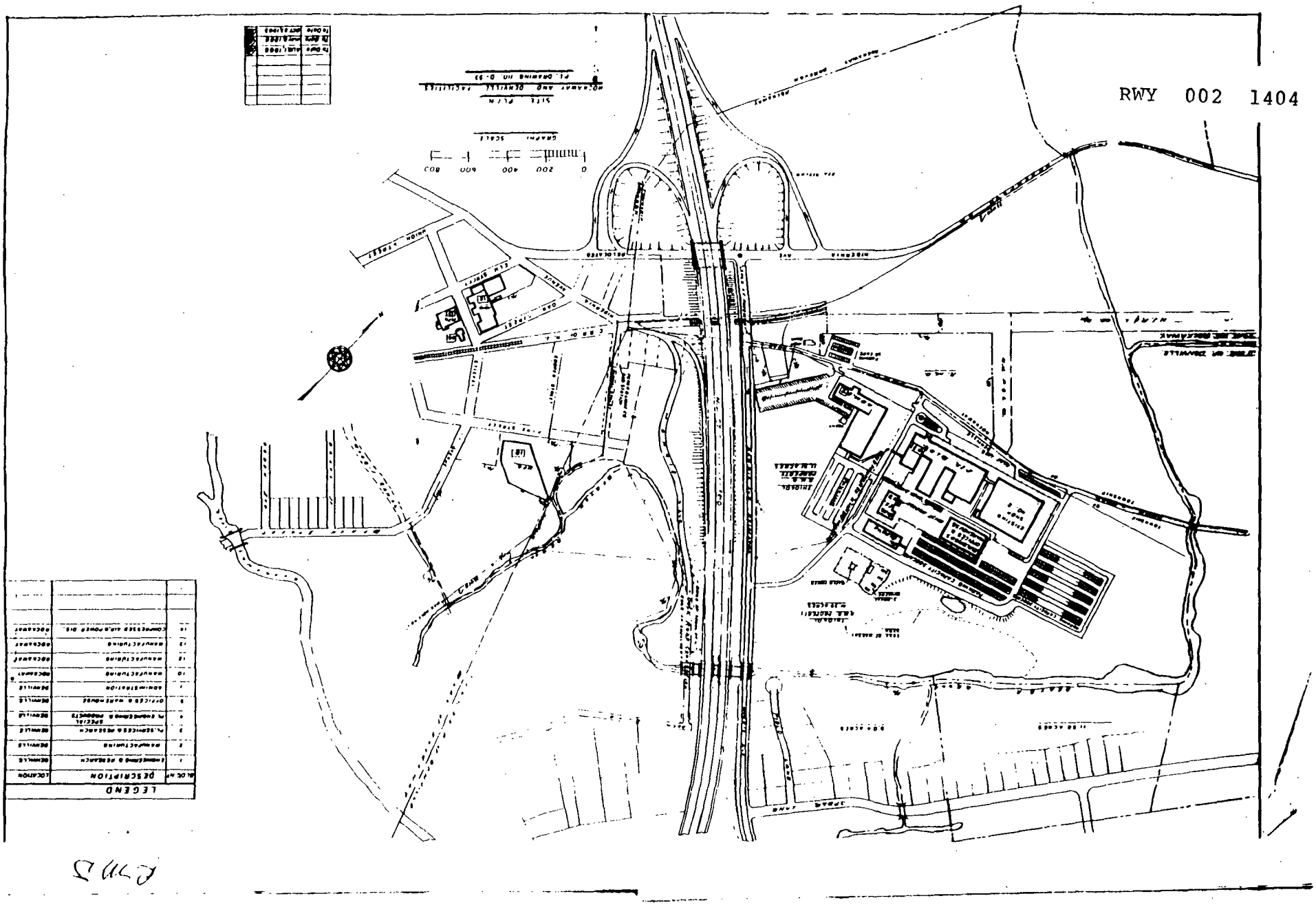
Viking No.	Date	Length (feet)	Diameter (inches)	Weight (pounds)			Altitude (miles)	Velocity (mph)	Thrust (pounds)	Firing time (seconds)
				Loaded	Propellant	Payload				
1	3 May 1949	45.25	32	9.650	6.855	464	50	2.350	20.450	54.5
2	6 September 1949	48.5	32	9.885	7.265	412	32	1.820	20.465	49.5
3	9 February 1950	47.4	32	11.050	8.310	328	50	2.340	20.450	59.6
4	11 May 1950	48.6	32	11.440	8.280	690	105	3.580	20.430	74
5	21 November 1950	48.6	32	11.390	8.430	675	108	3.310	18.800	79
6	11 December 1950	48.6	32	10.880	8.380	373	40	2.740	20.800	70
7	7 August 1951	48.6	32	10.728	8.257	394	136	3.998	21.080	71.8
8	6 June 1952	41.6	45	12.810	9.370	[a]	4	—	21.400	61
9	15 December 1952	42	45	14.615	11.743	785	135	3.940	21.170	99
10	7 May 1954	42	45	14.730	11.815	830	136	3.900	20.980	100
11	24 May 1954	42	45	15.005	11.983	825	158	4.300	21.400	103
12	4 February 1955	43	45	14.815	11.805	887	144	4.025	20.800	102
13	8 December 1956	48.5	45	15.035	12.010	[d]	126[b]	4.297	20.266	105.9
14	1 May 1957	47.5	45	15.030	11.876	[d]	120[c]	3.780	21.429	99.9

[a] Destroyed during static test (broke away from launching stand); did not carry payload.
[b] Range, 183 miles.
[c] Range, 450 miles.
[d] Carried Vanguard carrier vehicle elements.

Source: Von Braun-Ordway History of Rocketry and Space Travel, 1966, 1969, 1975.

RWY 002 1403

RWY 002 1404



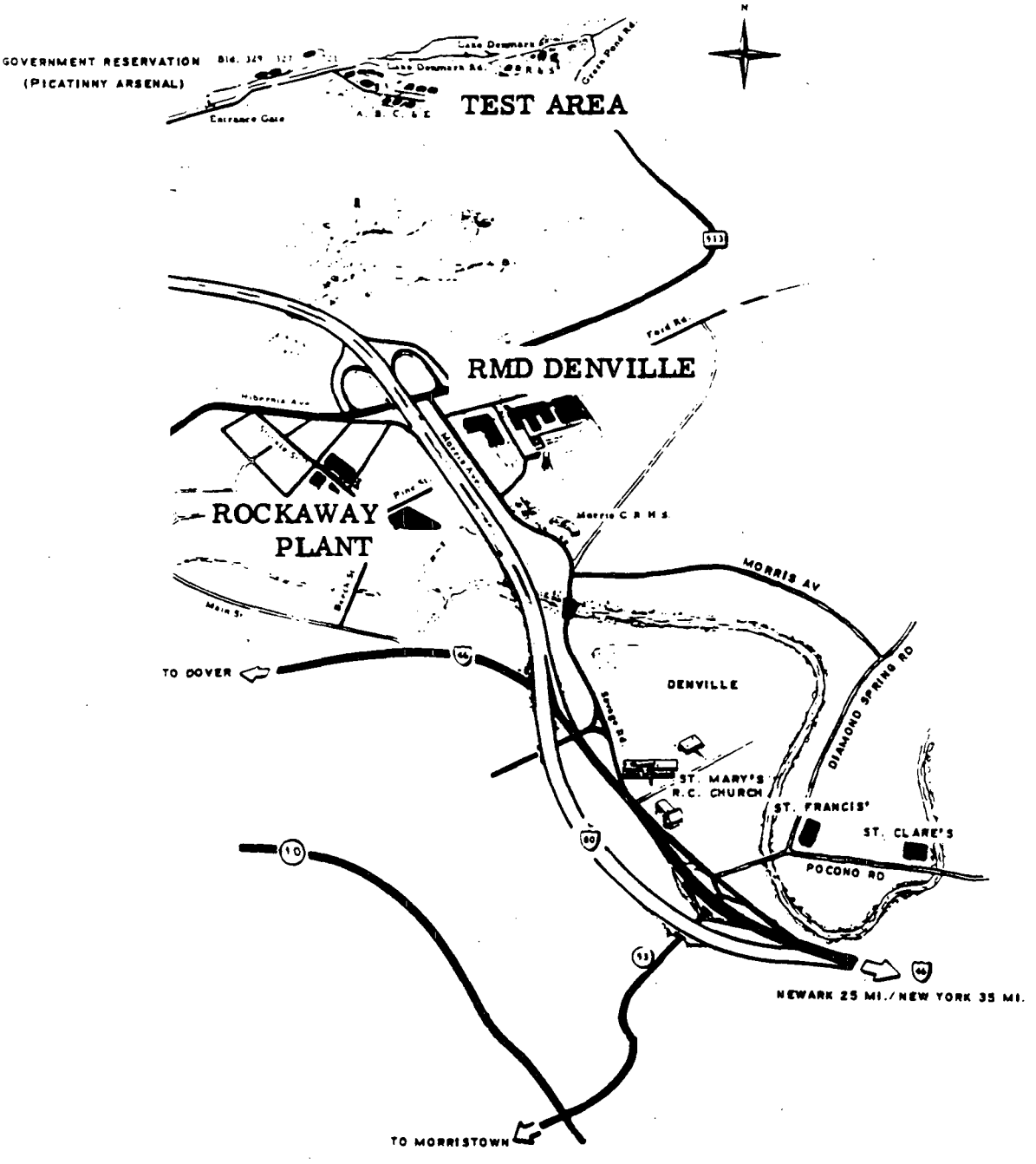


Figure 3-17. Location of Thiokol-RMD Facilities

EXHIBIT NO. 5

cc: T. Hitt
E. Laird
S. Wyatt

This AGREEMENT OF LEASE, Made in the Township of Denville, County of Morris, and State of New Jersey, as of 2 November 1959 by THOMAS E. HEATHCOTE and BLANCHE I. HEATHCOTE, his wife, and DANIEL KLOCKNER, JR. and MARTHA S. KLOCKNER, his wife, herein called the Landlord, and THIOKOL CHEMICAL CORPORATION, REACTION MOTORS DIVISION, a corporation of the State of Delaware having its division office at Ford Road, Denville Township, New Jersey, herein called the Tenant,

WHEREAS, the Tenant (which term as used herein includes its predecessor, Reaction Motors, Inc.) has been occupying the premises hereinafter described under Lease from the Landlord dated 1 May 1949 as amended and renewed from time to time, and

WHEREAS, with the effective date of this Lease, namely, 1 June 1960, it will supersede all previous and existing leases, agreements and options concerning the leasing of said premises by the Tenant.

WITNESSETH:

1. That the Landlord herein lets to the Tenant and the Tenant hereby hires from the Landlord, all those certain tracts and parcels of land, situate, lying and being in the Borough of Rockaway, in the County of Morris, and in the State of New Jersey, and more particularly described as follows:

BEGINNING at a point where the northerly side line of Stickle Avenue intersects the easterly side line of Elm Street as shown as a map entitled "Map of Property at Rockaway, N. J. - belonging to B. K. and C. W. Stickle - surveyed, laid out and drawn by Lewis Van Duyne City Surveyor - Boonton, N. J. - 1887" and filed in the Morris County Clerk's Office on April 6, 1892 as Map #172 in Case A and running thence (1) along said easterly side line of Elm Street North 22 degrees 30 minutes East 125 feet

11

RWY 002 1406

to a point; thence (2) South 67 degrees 10 minutes East 250 feet to the westerly side line of Oak Street; thence (3) along said westerly side line of Oak Street South 22 degrees 50 minutes West 125 feet to the intersection of the same with said northerly side line of Stickle Avenue; thence (4) along said northerly side line of Stickle Avenue North 67 degrees 10 minutes West 250 feet to the intersection of the same with said easterly side line of Elm Street and the point or place of BEGINNING.

BEING Lots Nos. 37, 38, 39, 40 and 41 as shown and designated on said Van Duyne map.

BEING the same premises conveyed by and described in a certain deed from Edwin J. Matthews, Executor and Trustee of George W. Stickle and others to Thomas E. Heathcote, dated June 24, 1944 and recorded August 23, 1944 in the Morris County Clerk's Office in Book H-38 of Deeds for said County at page 333 thereof; an undivided one-half interest whereof was conveyed by the said Thomas E. Heathcote unto Daniel Klockner, Jr., by deed dated August 25, 1947 and recorded September 10, 1947 in said Office in Book Q-43 at page 535 thereof. Together with all buildings thereon and attachments thereto.

2. The term of this Lease shall commence on 1 June 1960 and end on 31 May 1965.

3. The Tenant shall pay rent at the annual rental of Twenty-six thousand seven hundred and no/100 ($26,700.00) dollars, payable in equal monthly instalments each in the sum of Two thousand two hundred twenty-five and no/100 ($2,225.00) dollars, in advance, on the first day of every month during said term; said rent shall be paid to Thomas E. Heathcote and Daniel Klockner, Jr.

4. This Lease is made upon the following covenants and considerations each of which the respective parties hereto agree

to observe and perform:

(a) The Tenant shall have the right to use the land on the demised premises for purposes of parking or storage or such other use as the Tenant may desire.

(b) All electrical connections, service and wiring installed in the buildings on the premises will remain for the Tenant's use and the Tenant may rearrange such equipment except service. The Tenant shall have the right to install such other electrical equipment as it desires and as the [illegible] Tenant shall have the right to remove any electrical equipment installed by it (including electrical equipment heretofore installed by the Tenant).

(c) The Landlord shall leave the present fencing on the premises and the Tenant shall have the right to use the same for the protection of the plant. The Tenant may, at its own expense, place additional fencing on the demised premises and shall, at all times, properly maintain the fence. The Tenant shall have the right to remove from the demised premises any additional fencing placed thereon by the Tenant (including fencing heretofore installed by the Tenant).

(d) The Landlord will permit Tenant to construct sheds, lean-tos, and installations on any part of the demised premises. Tenant may, if the Landlord approves the general plan, construct a temporary addition on the main building on the demised premises. Tenant shall not be obligated to pay any rental at any time for the use of such sheds, lean-tos, installations or temporary addition. At the expiration of the Lease, Tenant shall have the right to remove said sheds, lean-tos, installations or temporary addition from the demised premises (including those heretofore installed by the Tenant). Tenant shall have the right to grade and landscape

the demised premises. Tenant shall have the right to construct parking areas on the demised premises at its own expense.

(e) Tenant shall have the right to install whatever partitioning, plumbing and equipment in the buildings on the demised premises as it deems necessary for its purposes and shall also have the right to make such modifications, installations and rearrangements inside the buildings on the demised premises as it deems necessary to its purposes providing the structure of the buildings is not materially affected. At the expiration of this Lease, Tenant shall have the right to remove any partitioning, plumbing and equipment so installed by it (including any heretofore installed by the Tenant).

(f) Tenant does hereby agree to make all interior repairs and will replace all glass which may be broken on the demised premises and the Landlord will make all exterior repairs except fencing.

(g) Subject to regulations of the approved local authorities and directives of the Armed Services, Tenant may use or permit the demised premises to be used for office space or for the engineering of or the manufacturing of any types of goods and products, but Tenant shall not use or permit the demised premises to be used for any other purposes without the written consent of the Landlord.

(h) It is hereby agreed that the Landlord accepts the installations, rearrangements, modifications, improvements and changes heretofore made by the Tenant in the demised premises. At the end of the term of this Lease, the Tenant shall restore the premises to the condition of the premises existing on 1 June 1960 subject to the Tenant's right to remove equipment et cetera, as specified in this Lease.

(i) The Tenant may assign this Lease, or re-let or under-let said premises, or any part thereof, but only with the written consent of the Landlord, which consent will not be unreasonably withheld, and the Tenant may without consent re-let the Lease or under-let the premises to an affiliate or successor of the Tenant hereunder.

(j) The Tenant will, at its own cost, promptly comply with and perform all statutes, ordinances, orders, requirements and regulations, present and future, of the Federal, State, County of Municipal authority, or agency or sub-division thereof affecting said premises, including the lands appurtenant thereto, provided however, that at the commencement of the term of this Lease, when the Tenant enters into possession of the demised premises and the buildings thereon, there shall be no violations thereof.

(k) Subject to regulations of the Armed Services, the Landlord, or their agents, shall be permitted, during the term of the within Lease, to visit and examine the premises at any reasonable hour of the day.

(l) Until otherwise agreed, any notice provided for by this Lease may be served either personally upon an executive of the Tenant or upon any one of the Landlords, or may be served by mailing the same, registered mail, postage prepaid, addressed to the Tenant at the division office at Ford Road, Denville, New Jersey, or to the Landlord at 6620 Estero Boulevard, Fort Meyers Beach, Florida.

(m) If at any time during the term thereof, the Tenant shall be adjudicated a bankrupt or an insolvent corporation; or if the Tenant shall compound its debts or assign its estate or effects for payment thereof; or if any execution shall issue against the Tenant or its property on the premises, and a sale

had thereunder; or if a receiver or trustee shall be appointed of the Tenant, or of its property, and said appointment is not vacated within ten (10) days after such appointment; or if this Lease shall, by operation of law, devolve upon, or pass to any person or persons other than the Tenant (except as a result of merger or consolidation), then and in any of such contingencies, this Lease shall, at the option of the Landlord, cease and come to an end, five (5) days after written notice to that effect shall be served by the Landlord upon the Tenant, or such receiver or trustee at the division office. Thereupon, at the end of said five (5) day period, the Landlord shall immediately become entitled to repossess said premises, and re-enter the same as of its former estate.

(n) Upon any breach or violation by the Tenant of any of the terms, covenants or conditions of this Lease, continuing for a period of twenty (20) days after written notice, the Landlord may, at their election, terminate this Lease, and upon such election, this Lease, and all the estate of the Tenant in said premises, shall come to an end, and the Landlord may thereupon re-enter the said premises as of its former estate; provided, however, that the Landlord may after said twenty-day period institute dispossess proceedings for the non-payment of any rent due hereunder, without the necessity of such notice; and provided further that if the breach or violation by the Tenant relates to any covenant other than the payment of rent, then the Landlord shall not be entitled to elect to terminate this Lease unless the Tenant fails, within said period of twenty-days, to begin to remedy the breach or violation complained of, and thereafter fails to diligently complete the remedying thereof. Any waiver by the Landlord of any breach shall not be deemed a waiver of any similar or other further breach. The rights and privileges herein reserved shall be, in addition to any remedy afforded to the Landlord, in the Courts of Law and Equity.

(o) If the premises shall become abandoned during said term, or if the Tenant shall be dispossessed or removed from said premises, or the term hereof shall end prior to the expiration date fixed herein because of any act or omission of the Tenant, or because of the happening of any contingency or event herein provided for or because of the election of the Landlord pursuant to the terms hereof, the Tenant does hereby authorize the Landlord, at its option, to re-enter the same as agent of the Tenant, or for its own account, or otherwise, to re-let the same, and to manage, operate, repair or remodel the same, if necessary or desirable for re-letting purposes, and to receive and apply the rent so received to the payment of the costs of such managing, operating, repairing, remodeling or re-letting, and the excess, if any, to the rents due hereunder. The Tenant shall not be entitled to any surplus accruing as a result of any re-letting, but shall remain liable for any deficiency. The Tenant having once abandoned or vacated the premises may not re-enter the same without the written consent of the Landlord.

(p) Nothing herein contained shall be construed as a consent on the part of the Landlord to subject the estate of the Landlord to liability under the Mechanics' Lien Law of the State of New Jersey, it being expressly understood that the Landlords' estate shall not be subject to such liability. This provision shall however, be effective only with the respect to services performed or materials supplied at the instance of the Tenant.

(q) In case the demised premises, or any part thereof, shall be damaged by fire, or the elements, then

(1) In case such damage should be so slight as not to interfere substantially with the use by the Tenant of the demised premises, the Landlord shall repair the damage as speedily as possible, and there shall be no abatement of rent; but if

(2) Such damage should render the demised premises untenantable in whole or in part, without causing a total des-

truction thereof, the Landlord shall repair the same as speedily as possible, and there shall be an abatement from the date of the fire until such repairs have been substantially complete, of so much of the rent as the rental value of the untenantable portion of the premises shall fairly bear to the rent of the entire demised premises.

(3) In case of a total destruction of the present main building on the demised premises, this Lease shall terminate ten (10) days after either party shall serve written notice to that effect upon the other, at which time the Tenant's rights to possession shall cease and come to an end. The Tenant shall pay all rent to the date of such destruction and the Landlord shall repay to the Tenant all rent paid in advance beyond such date including so much of the security as shall not have been applied to the monthly rent, as below provided.

(r) The Tenant agrees to remove or cause to be removed, as the need for the same arises, all snow and ice from the sidewalk in front of the demised premises and will keep the said sidewalk clean, and free from any and all fixtures, obstructions and encumbrances and will deposit ashes, garbage and other refuse in proper covered receptacles, and the Tenant further agrees that it alone shall be liable for any damage or injury to person or property caused by or resulting from any failure of the Tenant to comply with the provisions of this clause, and the Tenant agrees to indemnify and save the Landlord harmless from all loss or damage resulting therefrom.

(s) The Tenant will pay all personal property taxes assessed on its own personal property and will pay all charges for water, gas and electricity used by the Tenant. The Landlord will pay all other property taxes and special assessments and all insurance on the land and buildings. The Tenant shall pay the Landlord, as additional rent, twenty-three and 67/100 (23.67%).

percent of any amount by which the annual property taxes payable by the Landlord in any year of the term exceeds the property taxes assessed for the year 1959 (namely, $5,068.80). In the event of a reduction of taxes, Landlord will pay Tenant twenty-three and 67/100 (23.67%) percent of the amount by which the annual taxes are reduced below the taxes assessed for the year 1959 (namely, $5,068.80).

(t) The terms, covenants and conditions of the within Lease shall be binding upon, and enure to the benefit of each of the parties hereto, their respective executors, administrators, successors and assigns, as the case may be.

5. Tenant shall have the option to purchase the land and buildings comprising the aforesaid premises at any time during the term of this Lease or any renewal thereof for the sum of One hundred eighty-two thousand six hundred sixty-seven and no/100 ($182,667.00) dollars until 1 January 1965, at which time Tenant shall have the option to purchase the aforesaid land and buildings for the sum of One hundred seventy-five thousand and no/100 ($175,000.00) dollars during the remainder of this Lease, including any renewals thereof. Tenant will give notice of election under this option at least ninety (90) days before the date of the exercise of the option.

6. Tenant shall have the option to renew this Lease for an additional five (5) year period from 1 June 1965 to 31 May 1970 under the same terms and conditions herein, except the rental herein shall be increased by ten (10%) percent. This option may be exercised by Tenant giving written notice to Landlord by mail before 1 September 1964;

7. It is also stipulated and agreed by and between Landlord and Tenant that the Lease made heretofore on or about 1 May 1949 and the amendments thereto and exercises of option thereunder will be cancelled and terminated in all respects upon the commencement of this Lease on 1 June 1960.

IN WITNESS WHEREOF, the parties have hereunto set their hands and seals, and the corporate parties hereto have caused these presents to be executed by their duly authorized executives and officer, and their corporate seal to be hereto affixed.

SIGNED, SEALED AND DELIVERED
IN THE PRESENCE OF

_____

_____ L.S.
THOMAS E. HEATHCOTE

_____ L.S.
BLANCHE I. HEATHCOTE

_____ L.S.
DANIEL KLOCKNER, JR.

_____ L.S.
MARTHA S. KLOCKNER

THIOKOL CHEMICAL CORPORATION
REACTION MOTORS DIVISION

ATTEST:

_____ BY _____

_____ BY _____

RWY 002 1415

STATE OF NEW JERSEY)
: ss.:
COUNTY OF MORRIS)

BE IT REMEMBERED, that on this 21 day of November in the year of our Lord One Thousand Nine Hundred and Fifty-nine, before me, the subscriber, personally appeared THOMAS E. HEATHCOTE and BLANCHE I. HEATHCOTE, his wife, who, I am satisfied, are the Landlords mentioned in the within Instrument, to whom I first made known the contents thereof, and thereupon they acknowledged that they signed, sealed and delivered the same as their voluntary act and deed, for the uses and purposes therein expressed.

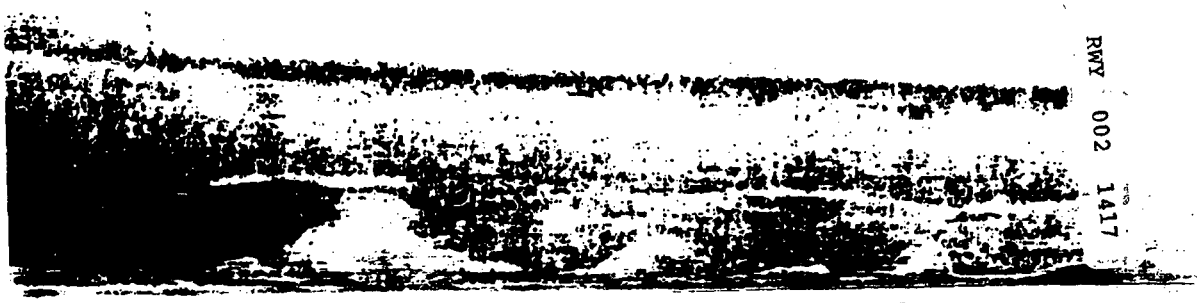
HERMAN C. MORITZ
NOTARY PUBLIC OF N. J.
My Commission Expires Feb. 2, 1963

RWY 002 1416

STATE OF NEW JERSEY)
: SS.:
COUNTY OF MORRIS)

BE IT REMEMBERED, That on this 12th day of November in the year of our Lord One Thousand Nine Hundred and Fifty-nine, before me, the subscriber, personally appeared DANIEL KLOCKNER, JR. and MARTHA S. KLOCKNER, his wife, who, I am satisfied, are the landlords mentioned in the within Instrument, to whom I first made known the contents thereof, and thereupon they acknowledged that they signed, sealed and delivered the same as their voluntary act and deed, for the uses and purposes therein expressed.

N. C. M. O. Z.
NOTARY PUBLIC OF N. J.
My Commission Expires Feb. 2, 1961



RWY 002 1417

STATE OF NEW JERSEY)
: SS.:
COUNTY OF MORRIS)

BE IT REMEMBERED, That on this 14th day of December in the year of our Lord One Thousand Nine Hundred and Fifty-nine, before me, the subscriber, a Notary Public, personally appeared WILLIAM F. CAMPBELL, JR., who being by me duly sworn on his oath, says that he is the Assistant Secretary of Thiokol Chemical Corporation, Reaction Motors Division, the Tenant named in the foregoing instrument; that he well knows the corporate seal of said corporation; that the seal affixed to said instrument is the corporate seal of said corporation; that the said seal was so affixed and the said instrument signed and delivered by RAYMOND W. YOUNG, who was at the date thereof the General Manager of said Thiokol Chemical Corporation, Reaction Motors Division, in the presence of this deponent and said General Manager, at the same time acknowledged that he signed, sealed and delivered the same as his voluntary act and deed, and as the voluntary act and deed of said corporation, by virtue of authority from its Board of Directors, and that deponent, at the same time, subscribed his name to said instrument as an attesting witness to the execution thereof.

William F. Campbell
WILLIAM F. CAMPBELL, JR.

Sworn and subscribed before me
at Denville, New Jersey,
the date aforesaid.

Notary Public

NOTARY PUBLIC, STATE OF NEW JERSEY
MY COMMISSION EXPIRES DEC. 30, 1962

RWY 002 1418

STATE OF NEW JERSEY)
: SS.:
COUNTY OF MORRIS)

BE IT REMEMBERED, That on this 14th day of December in the year of our Lord One Thousand Nine Hundred and Fifty-nine, before me, the subscriber, a Notary Public, personally appeared WILLIAM F. CAMPBELL, JR., who being by me duly sworn on his oath, says that he is the Assistant Secretary of Thiokol Chemical Corporation, Reaction Motors Division, the Tenant named in the foregoing instrument; that he well knows the corporate seal of said corporation; that the seal affixed to said instrument is the corporate seal of said corporation; that the said seal was so affixed and the said instrument signed and delivered by RAYMOND W. YOUNG, who was at the date thereof the General Manager of said Thiokol Chemical Corporation, Reaction Motors Division, in the presence of this deponent and said General Manager, at the same time acknowledged that he signed, sealed and delivered the same as his voluntary act and deed, and as the voluntary act and deed of said corporation, by virtue of authority from its Board of Directors, and that deponent, at the same time, subscribed his name to said instrument as an attesting witness to the execution thereof.

William F. Campbell
WILLIAM F. CAMPBELL, JR.

Sworn and subscribed before me
at Denville, New Jersey,
the date aforesaid.

Notary Public

NOTARY PUBLIC, STATE OF NEW JERSEY
MY COMMISSION EXPIRES DEC. 30, 1962

RWY 002 1419

EXHIBIT NO. 6

GROUND/WATER TECHNOLOGY, INC.

100 Stickle Avenue
P.O. Box 316
Rockaway, New Jersey 07866
(201) 625-5558 or (201) 627-2100

July 3, 1986

Mr. Michael Suroweic
N.J. Department of Environmental Protection
Bureau of Industrial Site Evaluation
CN-028
Trenton, New Jersey 08625

Dear Mr. Suroweic:

SUBJECT: MASDEN INDUSTRIES - E.C.R.A. CASE #85551

At the meeting we had on site with Mr. Ted Hayes of NJDEP, several questions were raised by him concerning the history of the site. This letter is in response to those questions.

The main building was constructed in 1946 on what was an open field (refer to Site Plan drawing 85508-1). Next, an addition was built between 1948 and 1950 (portion along Oak Street). The shipping/receiving area by the loading dock was added about 1962-63. And finally, the portion currently occupied by Masden was built in 1964. The facility has always been connected to public water and sewers; to Mr. Klockner's knowledge, no wells or septic fields were ever on this site. There are no records of soil borings taken on any part of this facility.

There are two known connections to city sanitary sewers: one in the main office area along Stickle Avenue, 1946; the other on Elm Street from the Masden area, 1974.

The storm drain in Masden's parking lot was installed about 1972. The purpose of the area of newer pavement was to reconstruct a low portion in the pavement where water would pond. This was done in 1978, and the center catch basin was added at that time. There were never any tanks in that area.

The identified water wells in the area are shown on Drawing 85508-1.

RWY 002 1420

Finally, the floor pit, where the fuel lines from tank number 3 came into the building, will be filled and sealed if it is permissable to do so.

Should you require any further information regarding the site, please contact us.

Very truly yours,

GROUND/WATER TECHNOLOGY, INC.

Gary J. Cluen
Sr. Hydrogeologist

GJC:gw

MORETRENCH ENVIRONMENTAL SERVICES, INC.

NJDEP FAX # 609-633-1004

100 Stickle Avenue, Rockaway, New Jersey 07866
(201) 627-2100

July 23, 1987

Mr. Jim Nalbone
N.J. Department of Environmental Protection
Bureau of Industrial Site Evaluation
CN 028
Trenton, New Jersey 08625

RE: Masden Industries - Multiform Metals Division
Klockner & Klockner Property
Rockaway Borough, Morris County
ECRA Case #85551

Dear Mr. Nalbone:

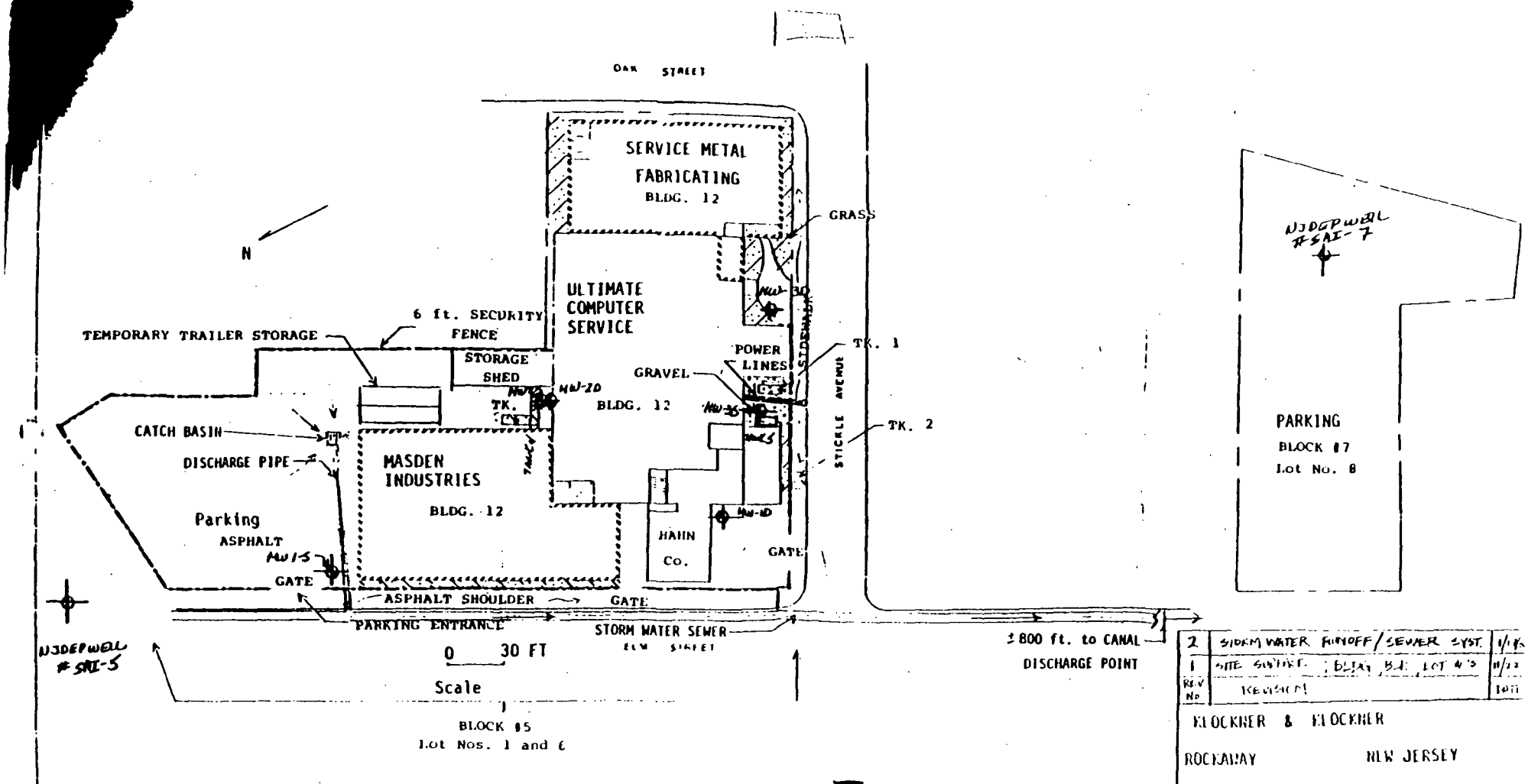
Results from the first round of sampling of monitor wells at the Klockner property has revealed the presence of volatile organic compounds with concentrations ranging from 23 to 388 parts per billion (ppb). Only four volatile organic compounds have been identified: trichloroethylene (TCE), tetrachloroethylene (PCE), t 1,2-dichloroethylene and bromoform. Volatile organics were found in each of the six wells.

Testing for petroleum hydrocarbons and base/neutrals on the three shallow wells all came back as "undetected". Testing for priority pollutant metals on the three shallow wells revealed: Arsenic (.004 to .014 ppm), Chromium (.009 to .028 ppm), Copper (.04 to .07 ppm), Lead (.09 to .047 ppm) and Zinc (.09 to .17 ppm); the other metal compounds were "undetected". All metals were within primary drinking water standards.

A summary table of testing results is attached. The second round of well sampling will be scheduled shortly. As part of the second round of sampling we intend to include the two NJDEP monitoring wells located to the north and south of the Klockner site. We will be in contact with Mr. Bob Gallagher shortly to schedule access.

As a result of the first round of sampling, it is apparent that the only contamination present is volatile organics. We request that the second round of sampling be limited to volatile organics only and that testing by GC scan instead of GC/MS be approved, since the four compounds of interest are known.

RWY 002 1422



RWY 002 1423

APPROXIMATE WELL LOCATIONS

EXHIBIT NO. 8

New Jeli Greenlabel
RMD - Site Plans

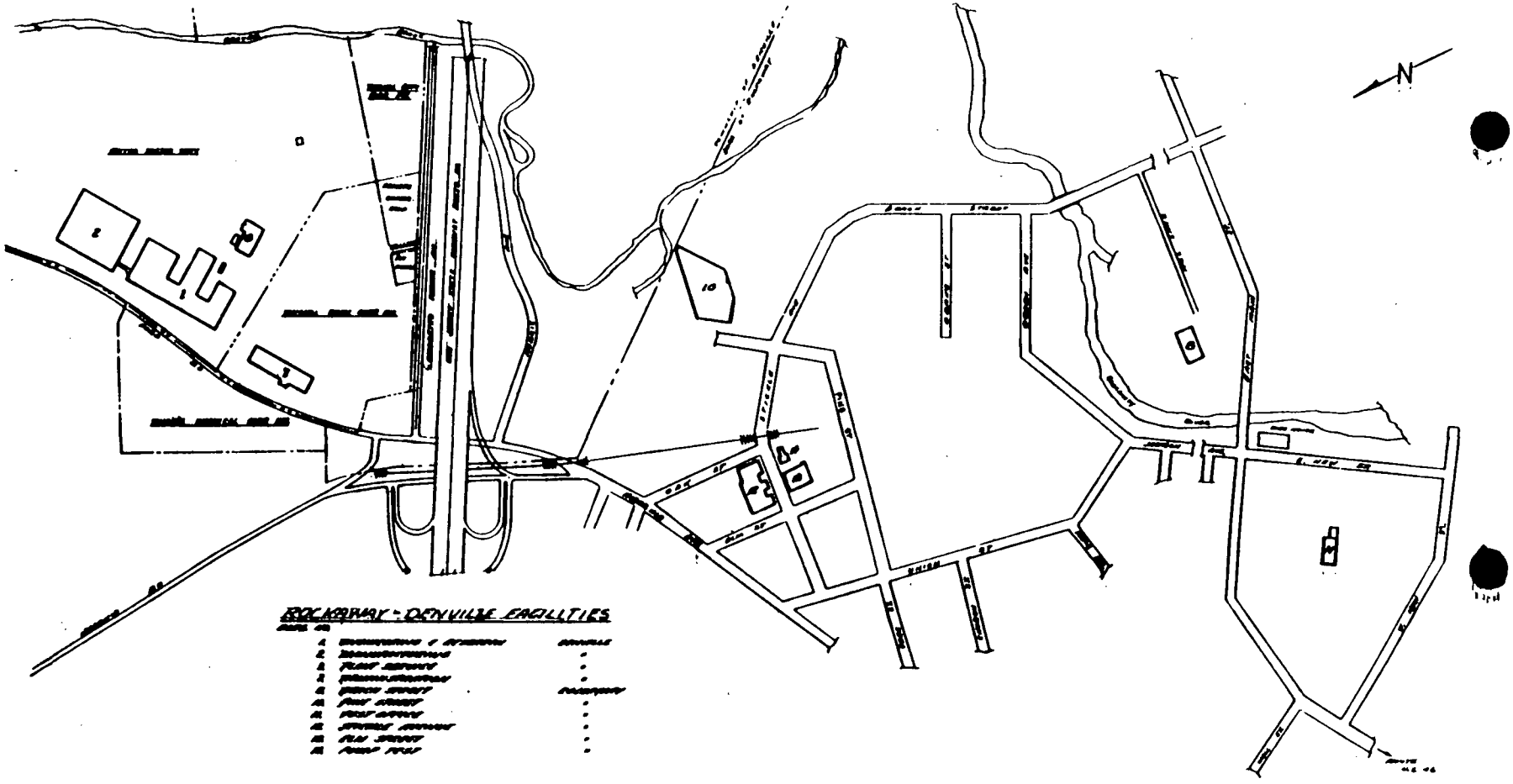
SITE PLANS

REACTION MOTORS DIVISION
THIOKOL CHEMICAL CORPORATION

DECEMBER 1958

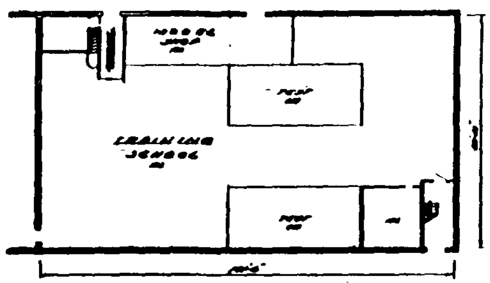
4/11/59

INDEX

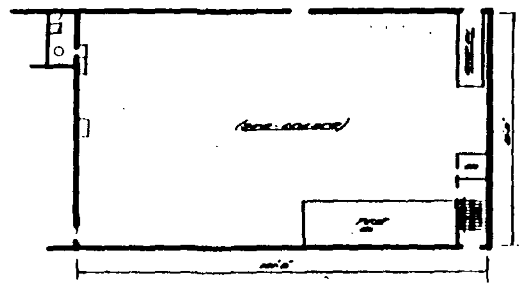


PLOT PLAN

BUILDING NO 8				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	990		990
	TRAINING SCHOOL	3970		3970
	CLASSROOM	420		420
[illegible]	TEST AREA	1873		1873
[illegible]	STORAGE	3966		3966
	TOILET	222		222
		11,440		11440
[illegible]	TEST AREA	750		750
[illegible]	[illegible]	80		80
	TOILET	175		175
	(SUB-TOTAL)	(1005)		(1005)
		12445		12445



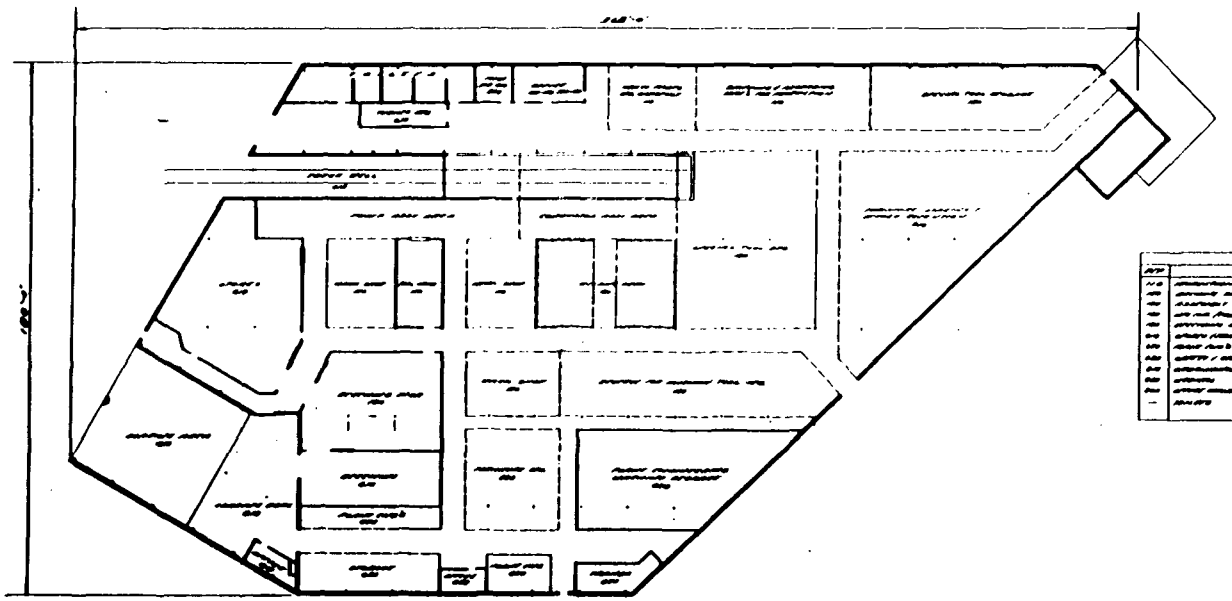
BASEMENT PLAN



1st FLOOR PLAN

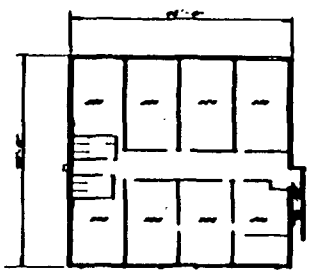
BUILDING NO 8

BEACH STREET BLDG ROCKAWAY N.J.



BUILDING NO.				

FIRE PUMP
BUILDING NO. 10
POST OFFICE BLDG. BROADWAY, N.J.



BUILDING NO. 11				

ARLENE FIRE PUMP
BLDG. NO. 11
POST OFFICE BLDG. BROADWAY, N.J.

RWY 002 1428

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	BUILDING #18			
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[illegible]	[illegible]	[illegible]		[illegible]
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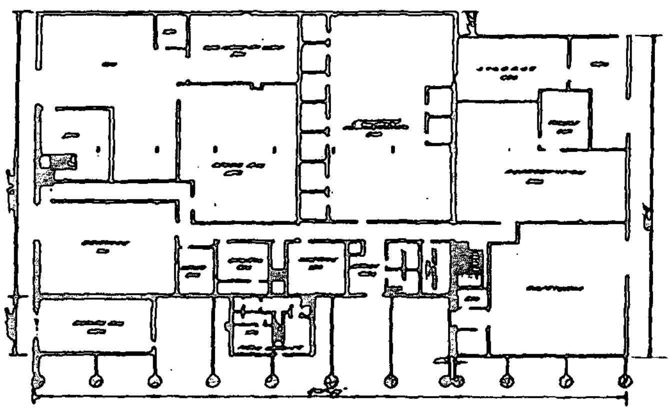
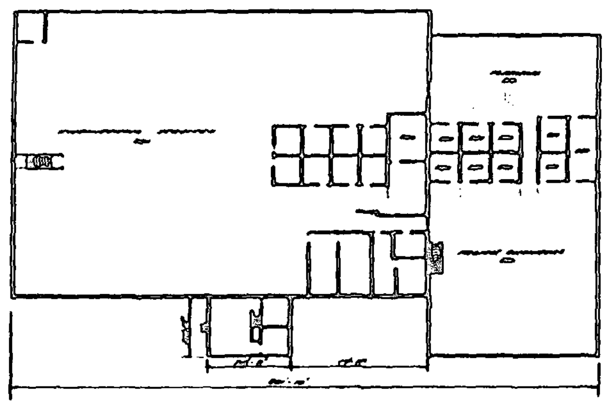


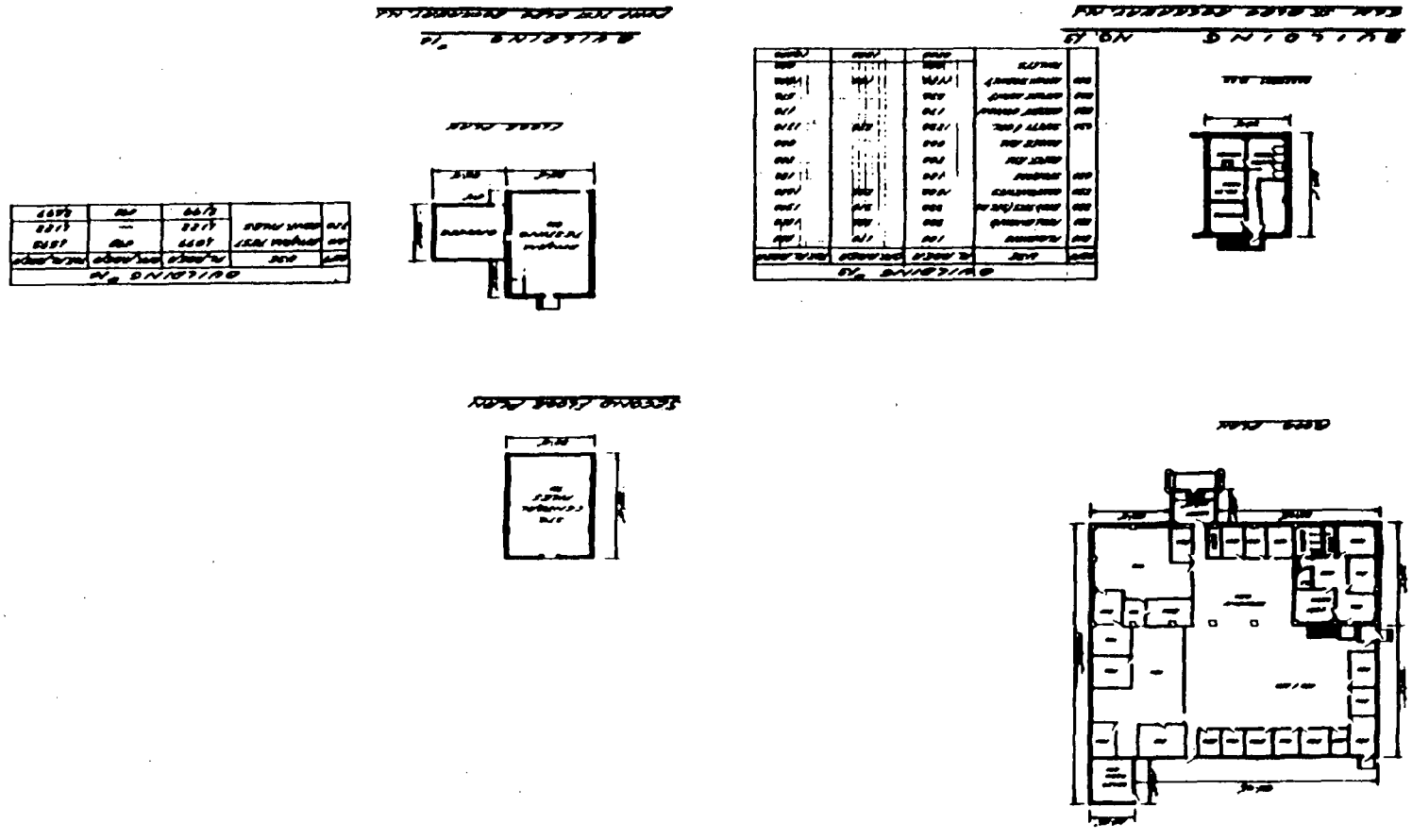
FIRST FLOOR



SECOND FLOOR

BUILDING #18

SENECA ARMY DEPOT, ROMULUS, NY



Site Plans

New File
(Red Label)
RMD - Site Plans

SITE PLANS

THIOKOL CHEMICAL CORPORATION
REACTION MOTORS DIVISION

30 June 1959

RWY 002 1431

AE 10/30/59

INTRODUCTION

Thiokol Chemical Corporation, Reaction Motors Division is organized, staffed, and equipped with personnel, equipment, and facilities to provide research, development and testing for rocket engines, component parts, and propellants. It is also geared for the production of rocket engines and component parts for aircraft and guided missiles.

Reaction Motors Division occupies 486,538 sq ft of covered structures including test areas on approximately 350 acres of land. Present plans call for an additional 69,269 sq ft of covered area to be available during 1959. Figure 1 shows the geographical locations of the various RMD facilities.

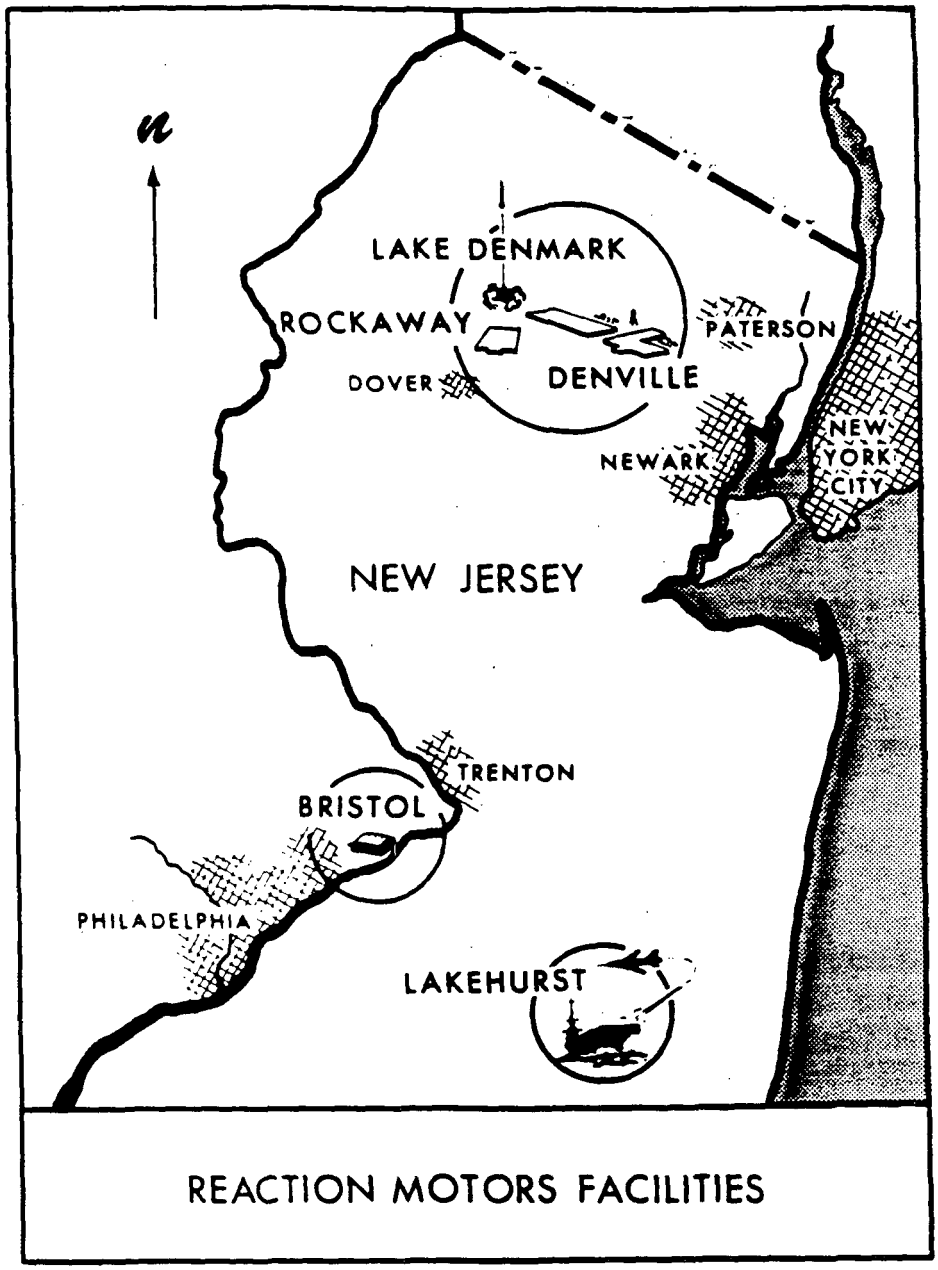


Figure 1

67-1208

Denville - Rockaway Facilities
Figure 2

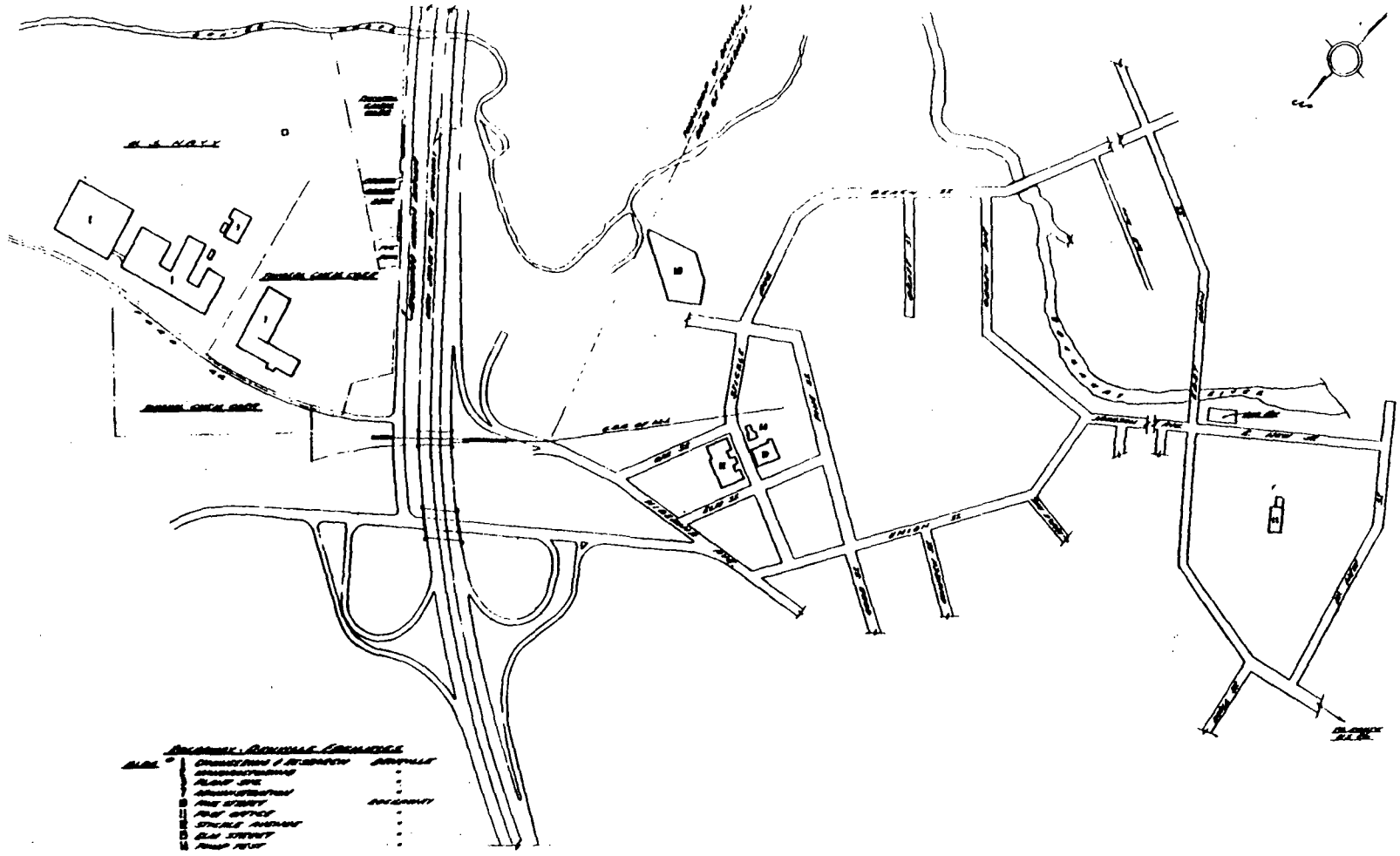


Figure 3

67-1208

Figure 2a

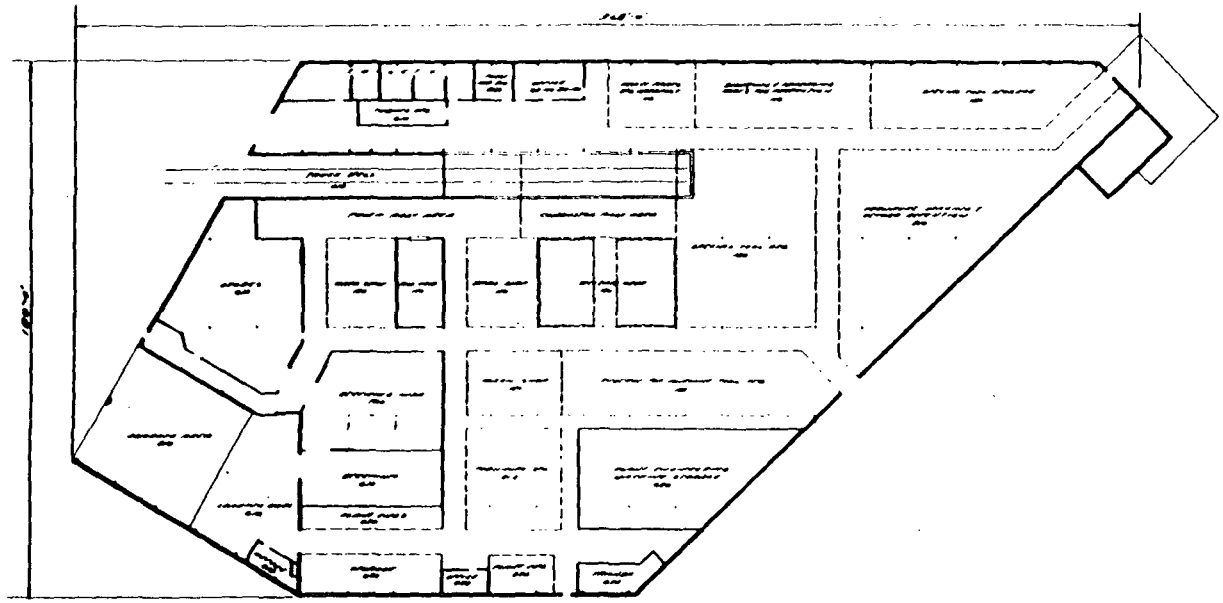
RWY 002 1436

Rockaway - Building No. 10, Pine Street, is a masonry steel framed building leased to RMD. This single story building is located on 10 acres of land and can readily be expanded for production facilities if the occasion demands. A catapult assembly facility and storage now occupies the building.

Utilities Available - Usage and Expansion

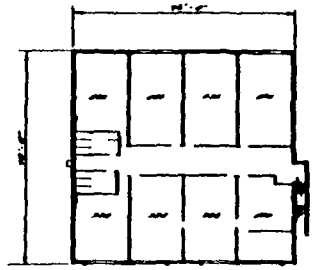
Utility	Present Usage	Available for Expansion
Water	15gpm	65gpm
Electricity	100 kva	200 kva
Sewerage	4 in. Sewer	--
Steam (Heating)	100 hp	175 hp
Compressed Air	300cfm	--
Natural Gas	Negligible	4,000 cfh

Rockaway - Building No. 11, Post Office, is a cinderblock, stucco building. The second floor is leased for use by Division and Corporate service type offices.



FLOOR AREA	OFFICE AREA	TOTAL FL AREA
15,134	446	15,900

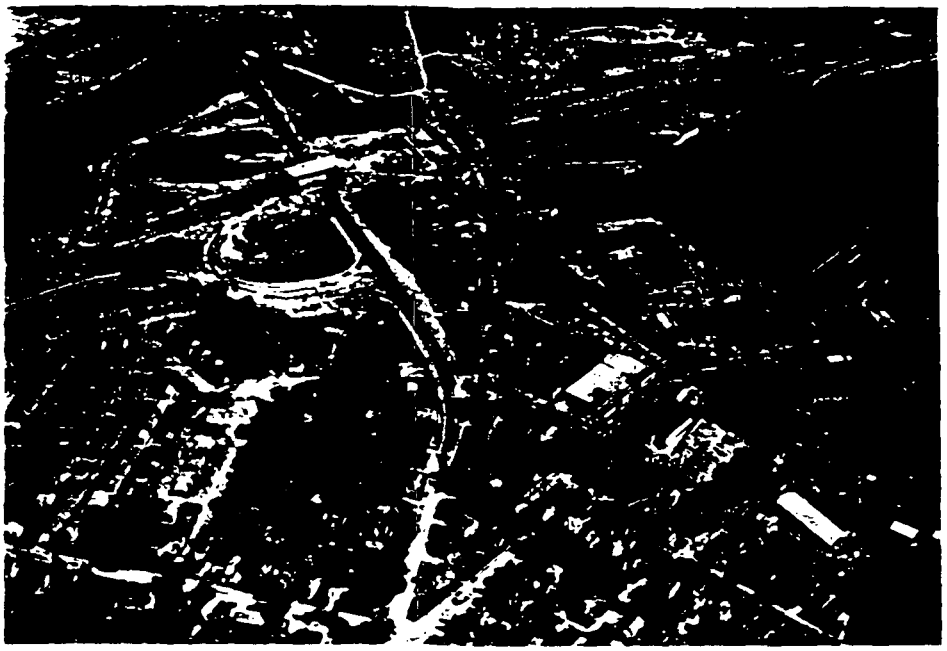
FLOOR PLAN
BUILDING NO 12
POST OFFICE BLDG ROCKAWAY, NJ



FLOOR AREA	OFFICE AREA	TOTAL FL AREA
5396		5396

SECOND FLOOR PLAN
BLDG NO 12
POST OFFICE BLDG ROCKAWAY N.J

Figure 10

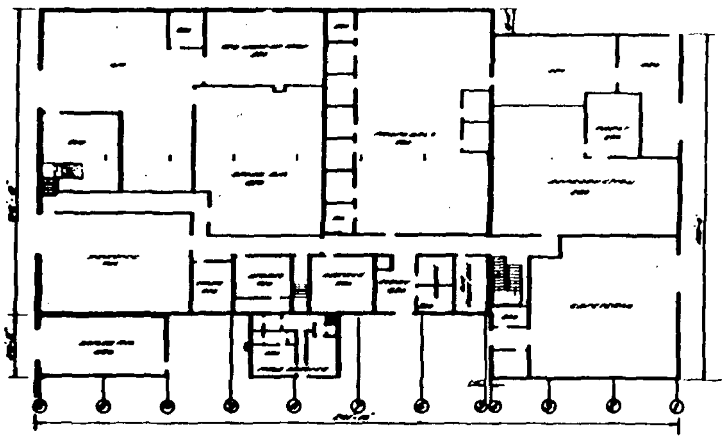


67-1208

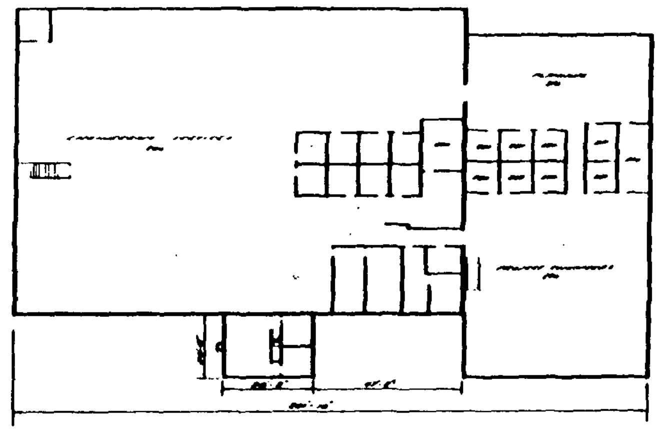
Rockaway - Building No. 12 is a steel framed, concrete block, two-story structure. Building No. 13 is a steel framed, concrete block, single story building with a partial basement. Building No. 14 is a two-story wood framed masonry building. These three buildings are leased to RMD. Building No. 12, houses Engineering offices, cafeteria and services. Building No. 13, is also used for Engineering offices and services. Building No. 14, is used for Turbopump Lab and storage. Adequate utilities exist for these buildings with capacity for a much higher electric demand load available for any future manufacturing requirement.

Figure 2B

FLOOR AREA	OFFICE AREA	TOTAL FL. AREA
38,647	3,760	42,407



FIRST FLOOR



SECOND FLOOR

BUILDING #12

STICKLE AVE BLDG. ROCKAWAY, N.J.

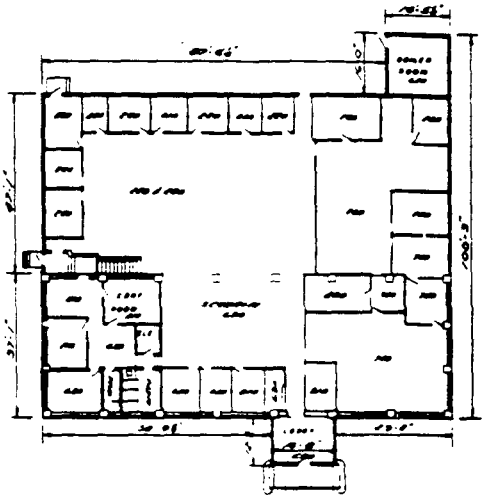
Figure 11

BLDG NO 13

FLOOR AREA	OFFICE AREA	TOTAL FL. AREA
8200	1850	10500

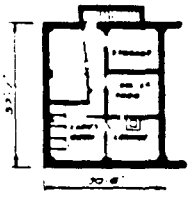
BLDG NO 14

FLOOR AREA	OFFICE AREA	TOTAL FL. AREA
2199	498	2697



FLOOR PLAN

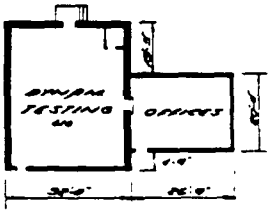
SECOND FLOOR PLAN



BASEMENT PLAN

BUILDING NO 13

ELM ST BLDG ROCKAWAY, NJ



FLOOR PLAN

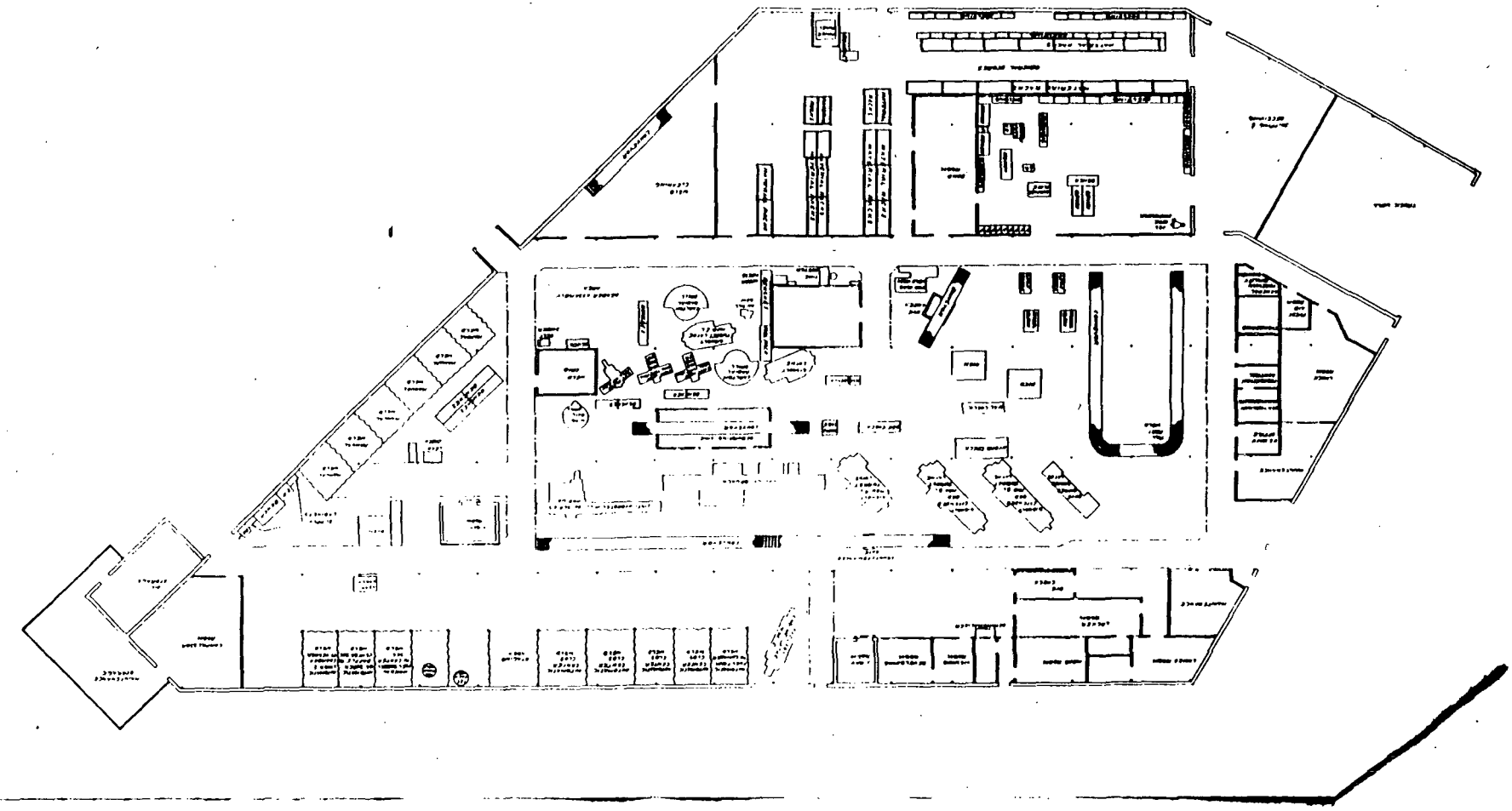
BUILDING "14

PUMP TEST BLDG ROCKAWAY NJ

Figure 12

RWY 002 1442

EXHIBIT 10.9



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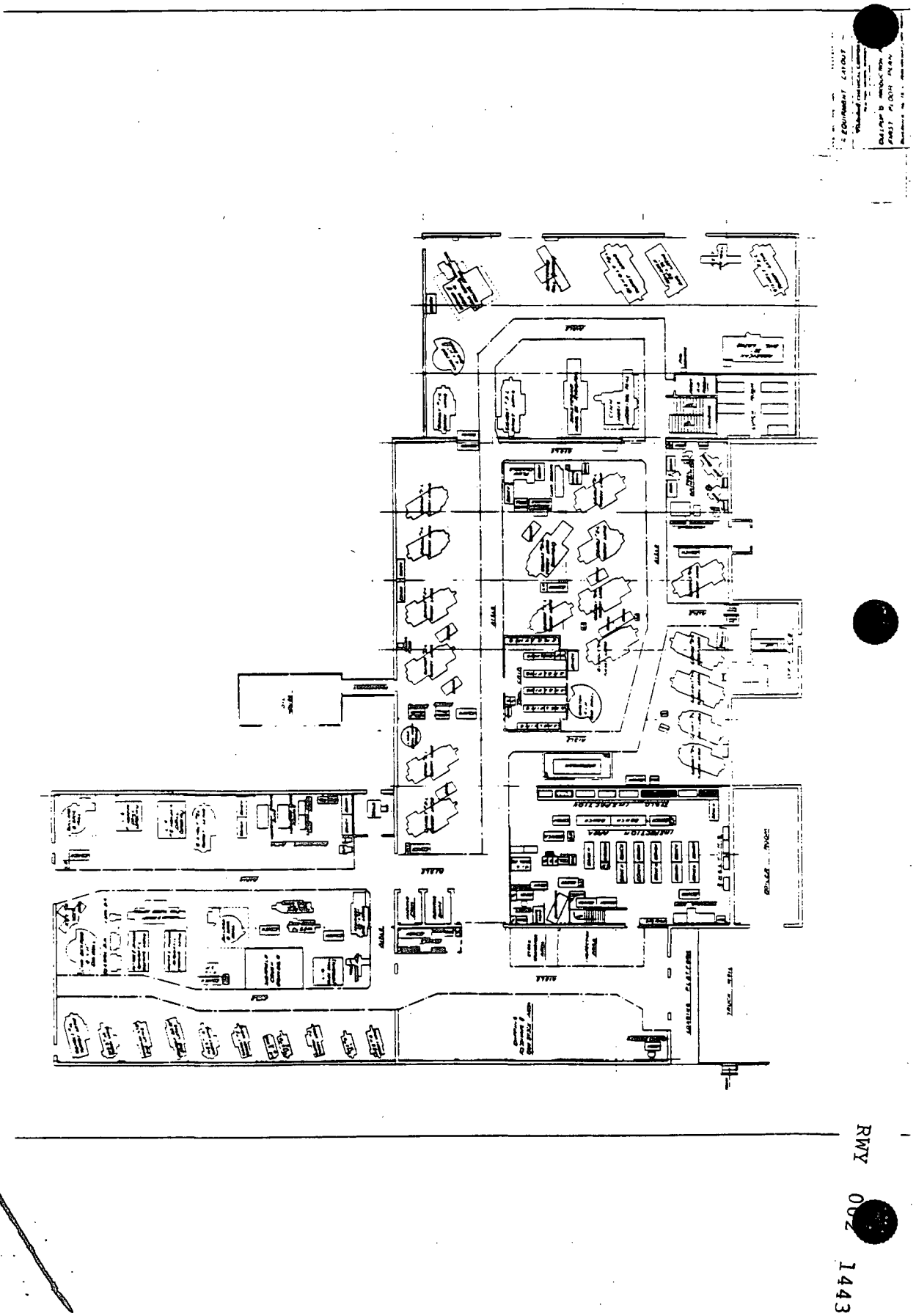


RWY 002

1443

RWY 002 1444

EXHIBIT NO 11

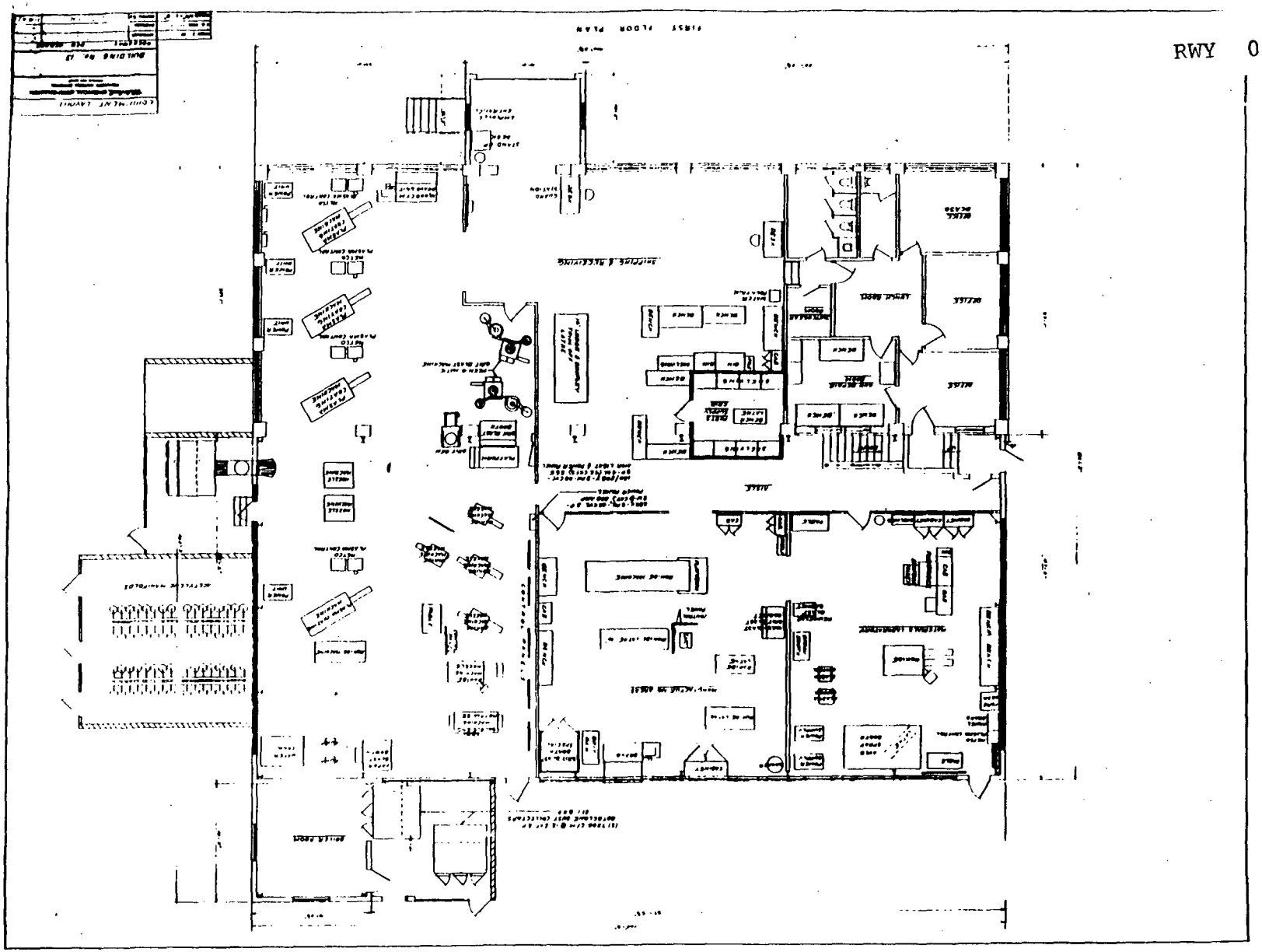
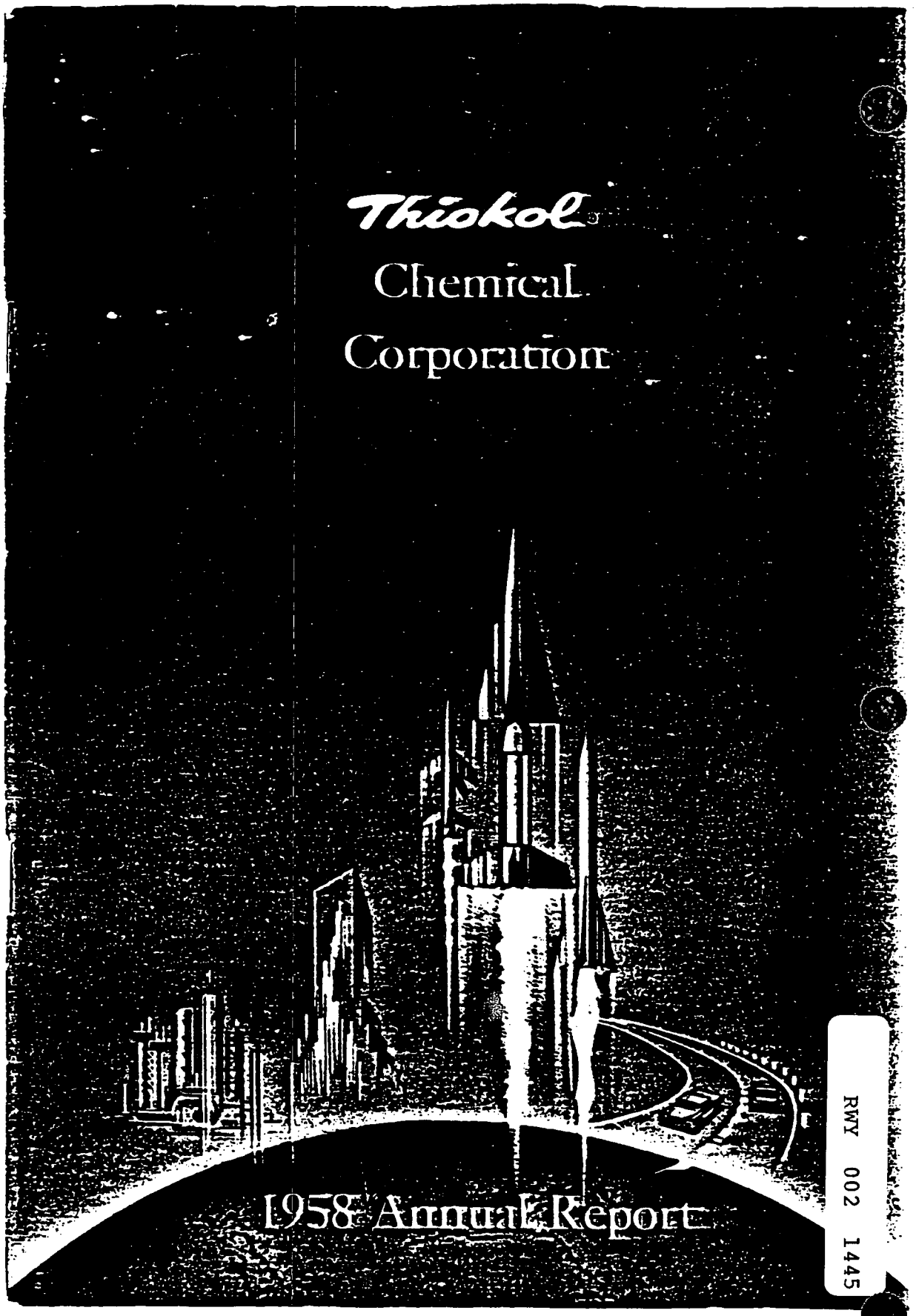


EXHIBIT NO 12

Thiokol Chemical Corporation



1958 Annual Report

REPORT *to the Shareholders of Thiokol Chemical Corporation*

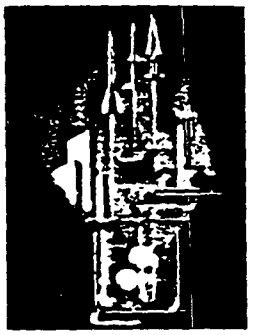
The accomplishments during 1958 are reflective of the loyalty, know-how and energetic teamwork of all the employees of the Company, numbering 7,444 at the year end. The results of this splendid, cooperative effort are indicated in the sales of $88,993,121 and net profits of $3,007,699 for the year 1958, the largest in the history of our Company. Based on the 1,465,973 shares outstanding at the year end, net earnings for 1958 were the equivalent of $2.05 per share.

In March we acquired certain assets of the Hunter-Bristol Corporation whose primary facilities were located at Bristol, Pennsylvania. The principal objective was to obtain additional facilities to alleviate the congestion at Trenton. The Chemical Division established Urethane Laboratories at Bristol early in the year and in September the Executive Offices of the Corporation were moved to the newly acquired site. Facilities for the production of pre-packaged liquid rocket engines are now being readied at this new location.

With the approval of stockholders, on May 1 Reaction Motors, Inc. was merged into Thiokol Chemical Corporation. This merger greatly diversified the Company's activities, facilities and capabilities and placed it in a very strong competitive position to serve the requirements of the Department of Defense for both solid and liquid propulsion systems. Pursuant to the provisions of the agreement of merger, Mr. T. F. Walkowicz, Technical Advisor to Laurance S. Rockefeller, became a Director of the Company.

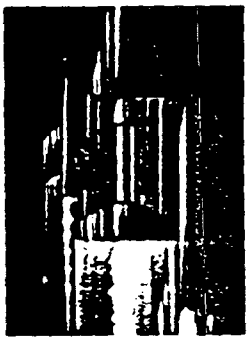
In January 1958 our stock was split on a two-for-one basis following the stockholders' adoption of a proposal to increase the authorized capital stock from 1,000,000 to 2,000,000 shares. Through the Subscription Offering on the basis of one new share for each 12 shares of Thiokol Chemical Corporation Capital Stock outstanding on September 17, 1958, 106,669 shares of stock were sold at the subscription price of $42 per share. In October we again declared a 5% stock dividend.

CHEMICAL DIVISION



Our Chemical Division has continued to expand through new markets, additional products and the growth in consumption of our products by established outlets, all of which led to total sales of $10,443,740, an increase of 43% over the previous year. Production at both the Trenton and Moss Point Plants was carried on at an increased rate during the year and production facilities at both plants were expanded. At the year end 398 people were employed by the Chemical Division, 60 of whom were located at Moss Point.

ROCKET DIVISION



All of our solid rocket plants have been taxed to capacity during 1958 and facility expansion programs are vigorously under way at each of the four locations. During the year the number of employees engaged in work at our solid rocket divisions increased by 2,435 to 4,877 at the year end. Acceptance of solid propellants for use in the larger missiles is one of the principal factors indicated by the increased activity reflected in the 98% increase during 1958 bringing our sales in the solid rocket field for the year to $45,954,066. Sales of Reaction Motors, chiefly in liquid propulsion, totaled $31,212,793 for 1958, an increase of 28% over 1957. Highlights concerning the divisions engaged in rocket work follow.

UTAH

To meet the increased workload construction was started on 57 new buildings or building additions in the manufacturing and testing

on which operations are carried out in more than 30 buildings. To meet the expanded requirements for solid propulsion systems, a $3,600,000 government facility expansion program, approved during the latter part of 1958, will add nine new buildings and place approximately 300 additional acres under the area assigned to THIOKOL. At the year end 1,809 employees, a large portion of which are scientists, were engaged in the work of our Redstone Division.

LONGHORN

The activities of our Longhorn Division are conducted at the government-owned Longhorn Ordnance Works near Marshall, Texas. During 1958 the volume of business increased by approximately 92% over that of the previous year while the number of employees increased approximately 51% to a complement of 1,352 at the year end. Government facility expansion programs completed in 1958 increased the value of the facilities in operation by approximately $1,500,000. During the latter part of the year an additional facility expansion program of $3,500,000 was approved by the government.

REACTION MOTORS

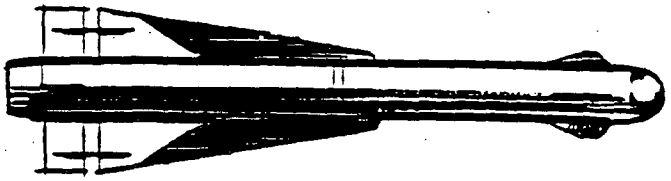
The Company's liquid propulsion work is conducted by the Reaction Motors Division with facilities located at Denville and Rockaway, New Jersey which are owned in part by the government. As a result of development efforts pioneered by the Reaction Motors Division in the field of packaged liquid power plants and because adequate facilities were not available at Denville and Rockaway, it was decided to establish at our Bristol location a facility to produce packaged liquid engines under contract with the Navy. At the year end the Reaction Motors Division employees totaled 1,815.

The dispersion of our Rocket Division activities affords close contact with the prime system contractors and the other segments of the missile industry with concentrations on the

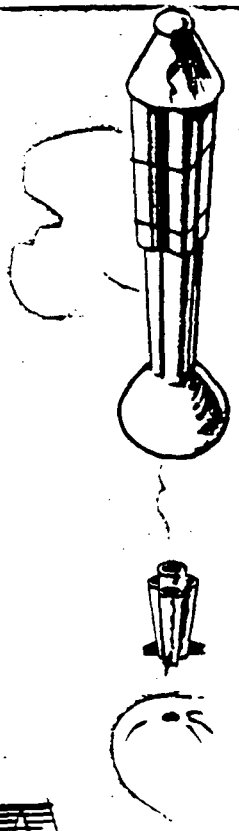
MISSILES

with motors by

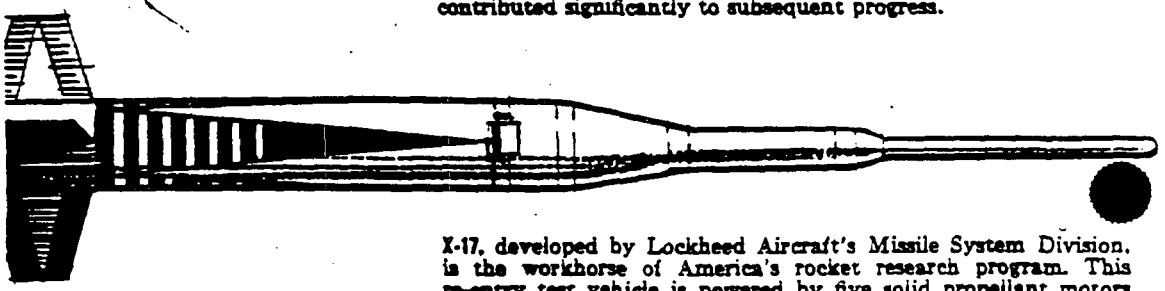
Thiokol®



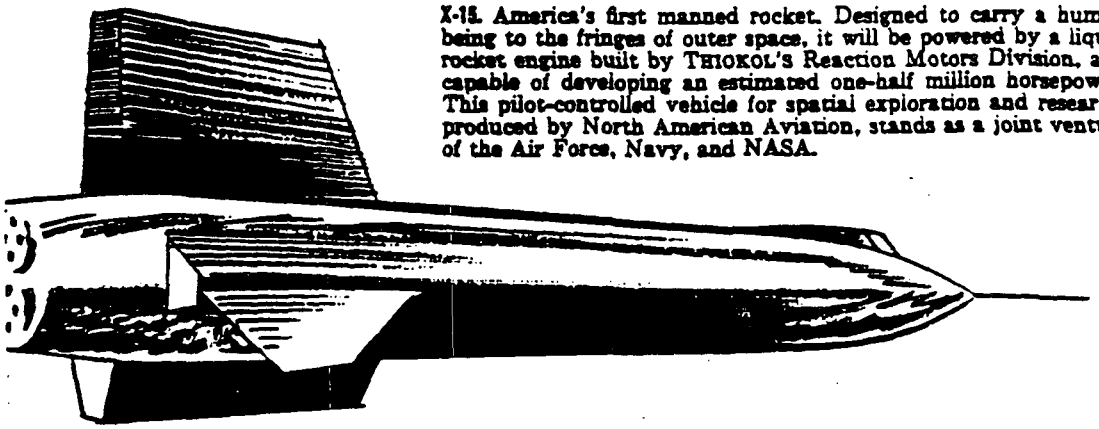
FALCON. An example of a true solid propellant guided missile power plant, the motor for the Air Force's FALCON was developed by THIOKOL in conjunction with the Hughes Aircraft Company. FALCON air-to-air missiles using this motor became operational early in 1956, and are now part of U.S.A.F. standard armament. They can be carried in quantity by interceptor aircraft, launched miles from the target. They are fired and guided electronically.



OPERATION FARSIDE, an early venture in spatial research, sent a man-made object some 4000 miles above the earth. Launched from a balloon at 100,000 feet, the Farside rocket relied on four THIOKOL solid propellant RECRUIT motors for its first stage, and a single RECRUIT for its second stage. The project helped space science gain much data which has contributed significantly to subsequent progress.

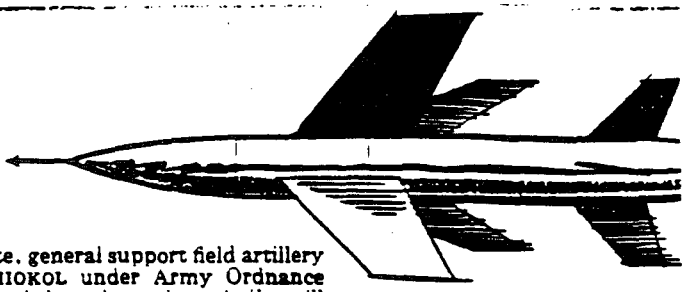


X-17, developed by Lockheed Aircraft's Missile System Division, is the workhorse of America's rocket research program. This re-entry test vehicle is powered by five solid propellant motors developed and produced by THIOKOL. They provide the high performance needed to help answer the problems of air friction at hypersonic speeds and the accompanying temperatures.

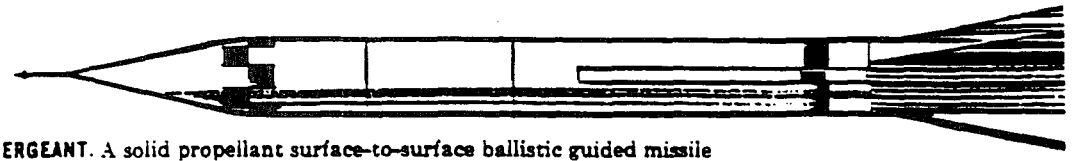


X-15. America's first manned rocket. Designed to carry a human being to the fringes of outer space, it will be powered by a liquid rocket engine built by THIOKOL'S Reaction Motors Division, and capable of developing an estimated one-half million horsepower. This pilot-controlled vehicle for spatial exploration and research, produced by North American Aviation, stands as a joint venture of the Air Force, Navy, and NASA.

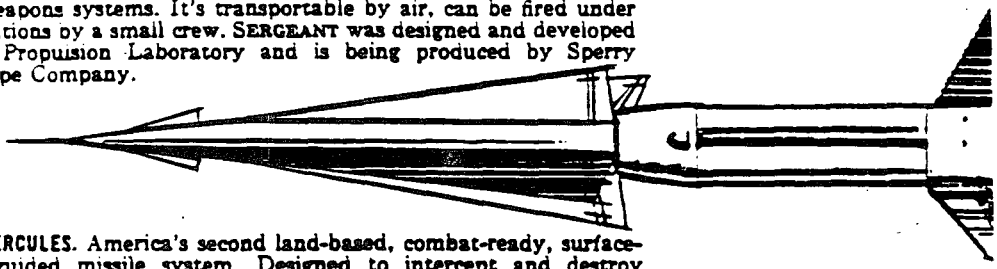
RWY 00[illegible]1449



LACROSSE. Motor for this highly accurate, general support field artillery guided missile was developed by THIOKOL under Army Ordnance contract. Fired from a truck mounted launcher, the missile will replace or supplement conventional artillery. Produced by Glenn L. Martin Co., LACROSSE is designed for close tactical support of ground troops, is capable of carrying area type warheads, accurate enough for destroying hardpoint targets.



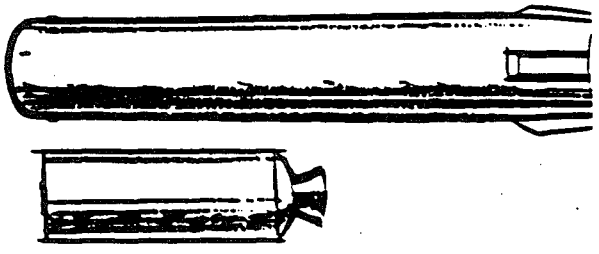
SERGEANT. A solid propellant surface-to-surface ballistic guided missile able to deliver a nuclear blow deep into enemy terrain and invulnerable to any known counter measures. SERGEANT—superior in power, range, accuracy—can be put into action more quickly than many other weapons systems. It's transportable by air, can be fired under all conditions by a small crew. SERGEANT was designed and developed by Jet Propulsion Laboratory and is being produced by Sperry Gyroscope Company.



NIKE HERCULES. America's second land-based, combat-ready, surface-to-air guided missile system. Designed to intercept and destroy targets at longer ranges and higher altitudes than its predecessor. NIKE HERCULES represents the joint efforts of Army Ordnance, Bell Laboratories, Western Electric, Douglas Aircraft, THIOKOL and numerous subcontractors.

MATADOR. This Air Force tactical missile operates surface-to-surface at subsonic speed ranges. Manufactured by the Martin Company, it is launched by a THIOKOL booster rocket which was developed and ready for flight test in the short span of 10 months. MATADOR is electronically controlled by ground personnel, is highly resistant to counter measures, can be deployed over wide expanses of water, will deliver an atomic warhead.

GUARDIAN I AND II. Pre-packaged liquid rocket engines developed and produced for the Navy by the Reaction Motors Division of THIOKOL CHEMICAL. They're factory fueled, include entire engine system, can be held in ready state for extended periods of time. Safe, flexible, this revolutionary liquid rocket engine development eliminates propellant handling in the field . . . lends itself to many missile applications.



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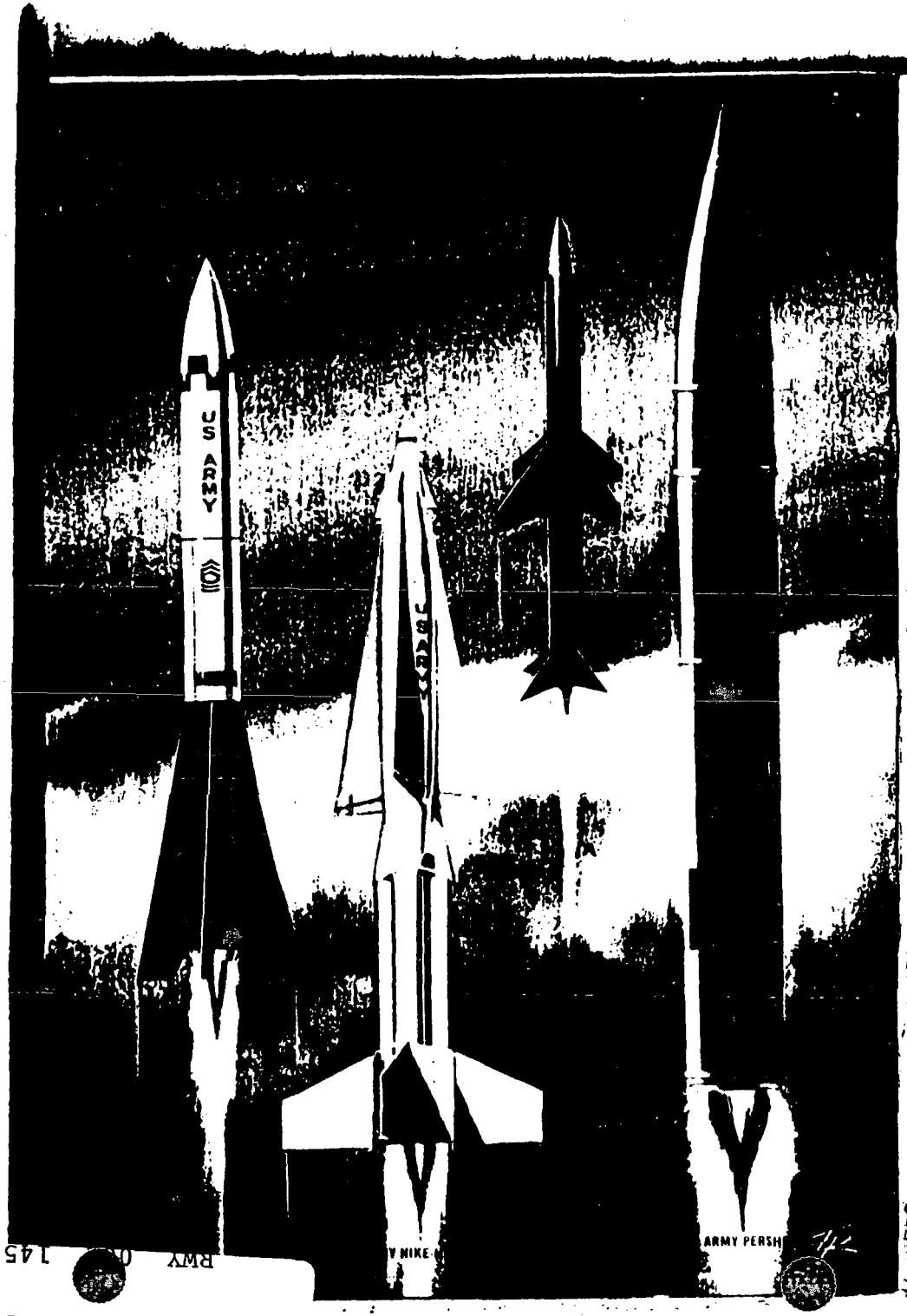


Thiokol

CHEMICAL CORPORATION

ANNUAL REPORT

1959

Elkton Division

Sales of our Elkton Division increased 62% during 1959. Elkton's Sarv Retrograde rocket engine operated successfully to return Discoverer VIII from orbit, and the Retrograde rocket which will help ensure the safe return from orbit of the Mercury Astronaut was designed, manufactured and satisfactorily test fired. An Elkton engine was successfully flight tested as the fourth stage of NASA's project Strongarm, which made atmospheric observations at an altitude of 1000 miles.

Elkton's 1000th Cajun engine was delivered in 1959. A Cajun was used with a cluster of other engines in establishing a new monorail sled speed record of approximately Mach 4.5 at Holloman Air Force Base. As the second stage of the Nike-Cajun, this engine propelled instrumentation for project HUGO which photographed the weather over the entire eastern seaboard for the first time.

A substantial portion of the work during 1959 was on Subroc under subcontract from Goodyear Aircraft Company. Subroc is a solid propellant missile, to be fired underwater, travel most of its course through the air, and return to the sea in search of its target.

Utah Division

The growth of the Utah Division has continued at a phenomenal rate. Sales increased 760%. The Company's investment in property, plant and equipment increased from $1,371,624 at the end of 1958 to $8,692,552 at the end of 1959. In addition to the investment in Utah facilities by Thiokol, the Air Force has undertaken a program extending through 1960 which will provide additional development facilities valued at approximately $10,000,000.

Research and Development work on large solid propell engines bore fruit in 1959 as Thiokol Chemical Corporat was selected by the Air Force to manufacture the first-st engine for the Minuteman ICBM.

While the major effort of the Utah Division was in c nection with the development of the Minuteman ICBM, Division also produces booster engines for the Martin Mat In addition, preliminary production of the new rocket boos for the improved Air Force long range surface-to-air missi Bomarc, has been performed under subcontracts with Boei Airplane Company.

Utah Production Division

In December the Air Force announced plans to constru a facility adjacent to our present Utah Division for the pr duction of first stage engines for the Minuteman missile. It understood that the Air Force will invest approximate $30,000,000 in this project. It is expected that Thiokol's i vestment for this purpose will approximate $2,500,000.

The Utah Production Division was established in D cember with the initial task of developing the engineerin criteria and plans for the production plant. In due course th new division will operate to produce first-stage Minuteman engines for the Air Force.

Reaction Motors Division

A high level of liquid propulsion work during the past ye resulted in an increase in sales of more than 11%.

Investment in property, plant and equipment at Denvill

and Rockaway increased by approximately $1,300,000 during 1959.

The pre-packaged liquid rocket engine has been introduced into two Navy missiles, the Sparrow III and the Bullpup. Production of the Sparrow engine, known as the Guardian I, was authorized by the Navy in May. The Reaction Motors Division Production Plant was established at Bristol, Pennsylvania. A production contract for the Bullpup engine, Guardian II, has already been awarded for a substantial number of these units. A contract to develop the third in the series of prepackaged liquid engines, to be known as the Guardian III, has been negotiated with the Navy.

The National Rocket Society recently awarded the Borg Warner trophy to Thiokol for its work on prepackaged propellants.

Development work on the engine, designed to power the X-15 piloted aircraft, was completed during 1959. Destined to fly man to the edge of outer space at a speed in excess of 4000 miles per hour, this engine is the most powerful aircraft engine and the only throttleable rocket powerplant in the country. Engines are currently being assembled and initial shipment of these units is expected to begin during the early months of 1960.

Another Navy missile, the Corvus, developed by Temco, will be powered by one of our liquid engines. Development work was completed on this powerplant during 1959 and production is now under way.

The successful completion of the development of the aircraft catapult launching program was accompanied by the

production and shipment of four catapult units for installation on the new Navy Nuclear-powered aircraft carrier, the Enterprise.

Increased activity in the development, production and promotion of special valves and other components for rocket engines has been a key program during the past year. This new area of activity is expected to become an even more important factor in the coming year.

SPECIALTIES OPERATIONS

Hunter-Bristol Division

Hunter-Bristol sales for 1959 were approximately double those of the preceding year. About 72% of these sales were interdivisional, over half of which was in connection with the Minuteman and Mercury programs.

During the last half of the year, efforts were concentrated on changing the major activity of the Division from engineering service to end products. The first major break through in that approach was a substantial contract from the Stanley Aviation Corporation for the development of a rocket ejector system for the B-58 pilot escape capsule. The program, which is shared with the Elkton Division, is well along in the development stages and will be followed by production during 1960.

The flexible shaped charge developed initially for missile technology as a precise method of cutting by use of explosives is now being tried for various commercial applications. Initial results are encouraging.

TELEGRAM

TO J. W. CROSBY, PRESIDENT
THIOKOL CHEMICAL CORPORATION

The record breaking X-15 flight on 7 March is a significant achievement in which the Thiokol Chemical Corporation can take justifiable pride. This and other flights of the X-15 have convincingly demonstrated the capabilities of the XLR99 rocket motors developed and produced by your Reaction Motors Division. This record breaking flight brought us a step closer to manned orbital and space flight, and we are looking forward to the continued success of this program. Please accept my congratulations to Thiokol for your contribution to this remarkable feat.

Bernard A. Schriever
Commander
Air Research Development Command

RWY 002 1455

TELEGRAM

TO J. W. CROSBY, PRESIDENT
THIOKOL CHEMICAL CORPORATION

The highly successful launch of the first Minuteman today is a significant demonstration of our progress in missile technology and particularly emphasizes the advances we have made in large solid propellant systems. This Minuteman flight was the first in the history of the free world in which a complete, multi-stage intercontinental missile, with all subsystems installed and operating was successfully tested on its initial flight. These major accomplishments can be directly attributed to the superior technical planning and outstanding program management continuously demonstrated by the members of the military industrial Minuteman team. To all personnel connected with the Minuteman Weapon System I extend my personal congratulations and a hearty well done.

Thomas D. White, Chief of Staff
United States Air Force
Washington, D. C.

As of now our long range projects in Chemical Operations are in better prospect than at any time in the past.

Volume of business was lower in all our Rocket Divisions except Utah (Wasatch is under construction). Changing military requirements, combined with long delays in time between the submission of proposals and contract awards, affected our volume and profits in 1960.

During the year we incurred costs in excess of original estimates under certain cost-plus-fixed-fee type contracts. These "overruns" are the result of unforeseen technical problems requiring additional funds without additional fee. The overall profit rate (in terms of percentage) was substantially reduced.

There were, however, very significant achievements that will cornerstone the Corporation's Rocket Operations progress and profits in 1961 and future years.

Chief among them were these successful programs for the armed services:

1. Pershing
2. Nike Zeus
3. Minuteman
4. XLR99 (liquid engine for the X-15)

Thiokol is the major propulsion supplier for these projects —in fact the sole supplier of propulsion in all except the

Minuteman. In that missile, Thiokol furnishes the all important first-stage booster that is so outstanding in proving the value of large solid propellant engines for space as well as military missions.

The performance records of Thiokol's liquid propelled XLR99 and solid propelled Minuteman in 1960 and early 1961 are two of the most significant and satisfactory developments in our nation's missile program. Tests on the Army's Pershing and Nike Zeus programs indicate future performance tests and operational records of comparable stature.

Thiokol's leadership in large solid propellant engines took giant strides in 1960 and early 1961. Flight tests demonstrated the reliability and economy of solid fuel propulsion units for space projects as well as for military purposes. Success of the Minuteman, climaxing other solid propellant performances, projected solids into future space projects at an accelerated pace.

These are achievements, best summarized in the messages of Generals White and Schriever reproduced on the inside back cover of this report.

Development work on the booster for the Bomarc B surface-to-air missile has been nearly completed. In test flights the booster engine performed without a single failure. The Company has been awarded a Bomarc B production contract. Although the development work on the Navy's Subroc is in earlier stages, present indications for this submarine-carried missile are also very promising.

Last spring we established our Rocket Operations Center at Ogden, Utah to strengthen all phases of our rocket activities and to serve our customers more efficiently. The staffs of the five district offices servicing Rocket Operations were also strengthened.

A Nuclear Development Center was established at Parsippany, N. J., during the year. A small contract from the Air Force was our first order. We are at present teamed with three major companies in proposals being submitted to the National Aeronautics and Space Administration and the Atomic Energy Commission.

During the year National Electronics Laboratories, Inc. was liquidated. The business was continued as part of Specialties Operations. Activities of National Electronics and Hunter-Bristol Divisions were reorganized to meet changing conditions in the specialty fields in which they operate.

In 1959 the Company organized a Corporate Planning Department to establish long range goals and a program for ultimate attainment of these objectives, which include development of new markets and new products (generated internally as well as by acquisition) with emphasis on diversification. This program has in two years shown promise of fulfillment. It will put the Company in excellent position to broaden its operations and meet constantly changing situations and competition.

Our Company esprit is excellent. Our engineers and scientists have done an outstanding job, evidenced by the brilliantly successful project fulfillment experienced during the past year. If from an earnings standpoint this was a disappointing year, after the great growth in 1959, it was also a year of achievement in coordination of operations and improved organization. This augurs well for success and better earnings in 1961 and the near future.

Respectfully submitted,

PRESIDENT

THIOKOL OPERATIONS AND TECHNICAL SERVICE LOCATIONS

DENVILLE, N. J.
Reaction Motors Division

PARSIPPANY, N. J.
Nuclear Development Center

TRENTON, N. J.
Headquarters, Chemical Operations

BRISTOL, PA.
Corporate Headquarters;
Headquarters, Specialties Operations;
Hunter-Bristol Division;
Reaction Motors Production Plant

ELKTON, MD.
Elkton Division

WASHINGTON, D.C.
National Electronics Division;
Washington Office

HUNTSVILLE, ALA.
Redstone Division;
Southeast District Office

MOSS POINT, MISS.
Production Plant Chemical Operations

CAPE CANAVERAL, FLA.
Technical Service Office

MARSHALL, TEXAS
Longhorn Division

DALLAS, TEXAS
Southwest District Office

DAYTON, OHIO
Central District Office

BRIGHAM CITY, UTAH
Utah Division;
Wasatch Division

OGDEN, UTAH
Rocket Operations Center

SEATTLE, WASH.
Technical Service Office

LOS ANGELES, CAL.
West Coast Chemical Division Office

EL SEGUNDO, CAL.
West Coast Rocket Office

LANCASTER, CAL.
Technical Service Office

Thiokol®

CHEMICAL CORPORATION

®Registered Trademark of the Thiokol Chemical Corporation for its liquid polymers, rocket propellants, plasticizers, and other chemical products.

Thiokol

CHEMICAL CORPORATION

BRISTOL, PENNSYLVANIA

ANNUAL REPORT

Thiokol

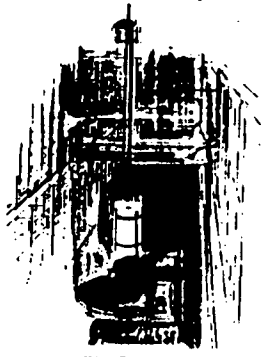
CHEMICAL CORPORATION

Spacecraft. Work also commenced on the design and the development of a solid propellant acceleration rocket engine for the Dynasoar manned space glider under contract with The Boeing Company.

Dynasoar moves into space

During the latter part of 1961 the Company acquired options on over 15,000 acres of land in Georgia and Alabama for strategic sites on which to construct facilities in anticipation of awards of contracts to Thiokol on the NOVA and other large solid fuel engines for space exploration work. Plant layout work and other preproduction efforts have been nearly completed and it is expected that construction could be commenced in the late Spring of 1962.

Sales of the Liquid Rocket Engine Division declined during 1961; however, in December production of pre-packaged liquid engines for the Bullpup missile commenced on a substantial scale. The pre-packaged liquid engine, a development of the Reaction Motors Division, shows great potential and is expected to be adopted as the propulsion system for a number of other missiles.



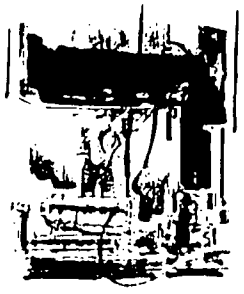
Big Booster capability at Pocatello

Programmed flights of the experimental piloted X-15 aircraft were successfully accomplished during 1961. Thirteen powered flights using the Thiokol XLR99 throttleable rocket engine brought successive altitude and speed records, until an altitude of 217,000 feet and a speed of 4,093 miles per hour were established on separate flights toward the close of the year.

TEMS, electronic monitor for power transmission equipment

Development and production of large valves and other components at Reaction Motors Division for handling cryogenic and other materials for the missile industry increased substantially during the year. Capability in this field is being extended to industrial applications.

Although Specialties Operations contributed but little to sales for 1961, developments resulting in new products were successfully completed and sales resulting from this effort will increase in 1962. The National Electronics Division is being consolidated with the electronics operations of the Bristol Division. The Company intends to expand its position in the electronics field and to build around the present product lines.



Machining packaged liquid engines

During 1961 Thiokol Chemical Corporation substantially expanded its facilities and operations by a series of acquisitions. Some of these acquisitions augmented

our existing business through enabling us to perform operations which formerly had to be subcontracted. Others of these acquisitions put the Company into entirely new businesses, primarily of a commercial nature or with substantial commercial potential.

The Company entered into a ten-year agreement, effective January 2, 1962, for the lease of most of the buildings and equipment of the former Naval Ordnance Depot at Pocatello, Idaho, with an option to buy these facilities at a price slightly in excess of $3,000,000. The Pocatello facility will be operated as an Annex to the Wasatch Division. Initial operations will involve storage, inspection and preparation work on inert components. We also expect to operate this facility to produce ground support and handling devices for use in the production of Minuteman and other large rocket engines.

As of December 31, 1961 Thiokol acquired the Trenton plant of the Panelyte Division of St. Regis Paper Company, in exchange for 117,256 shares of Thiokol Capital Stock, and is now operating the facility as the Panelyte Industrial Division. This new Division produces industrial plastic laminates in sheet, tube and rod form for the electrical, appliance, machinery and other industries; high pressure molded parts for electrical utility applications; and molded high temperature insulation parts for the aerospace industry. An intensified research and development program has been initiated to

Preparing material for lamination at Panelyte

provide for the extension and improvement of the present product lines. This acquisition should provide a substantial means for broadening the existing product lines of our Chemical Operations as well as the former Panelyte business.

In September 1961 the Company purchased 95% of the outstanding capital stock of Shawnee Industries, Inc., Shawnee, Oklahoma, in exchange for 2,850 shares of Thiokol Capital Stock. This subsidiary is equipped to perform sheet metal forming, welding and machining for a variety of industries.

In May 1961 Thiokol entered into an agreement with the Utah Scientific Research Foundation, an affiliate of Utah State University, giving Thiokol an exclusive license to manufacture and sell the Trackmaster vehicle developed by the Foundation. The Trackmaster is a tracked vehicle with unique capabilities for operation in snow, swamps and mountainous terrain, and has an existing market for military and many industrial applications. Production is now underway in leased facilities at Logan, Utah.

TRACKMASTER *vehicle traverses deep powder snow*

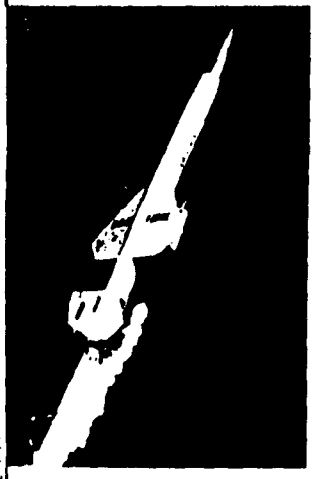
In the latter part of 1961 the Humetrics Division, headquartered in Los Angeles, was formed for the purpose of performing research and development in the broad field of life sciences, including behavior and engineering psychology, training, environmental physiology and bio-electronics. This program will mesh with present Rocket Operations

Rocket Operations
Expansion and Growth... *The Keynote In 1961*

During 1961 most of Thiokol's . . . and the nation's . . . key missile systems grew to maturity. With the success of Pershing, Minuteman, Nike Zeus, Bullpup, X-15, Bomarc and Mercury, the company expanded its capability to produce and develop critically required propulsion systems or rocket engines for defense missiles and the larger, more sophisticated systems for outer space.

The company has taken lease options on sites in Georgia and Alabama for possible production of large boosters. A ten-year lease with an option to buy a large existing plant in Pocatello, Idaho was also acquired.

NIKE HERCULES—Now being deployed around America's key cities as defense against aircraft attacks.
Prime Contractor: Western Electric.

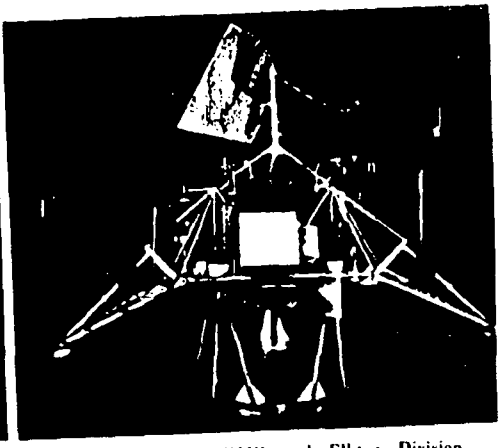


BOMARC B—First 36 were flight tested without a single booster failure.
Prime Contractor: Boeing.

BULLPUP — Prepackaged liquid engines, a Thiokol innovation, have given this system a propulsion unit of unique characteristics.
Prime Contractor: Martin-Marietta.

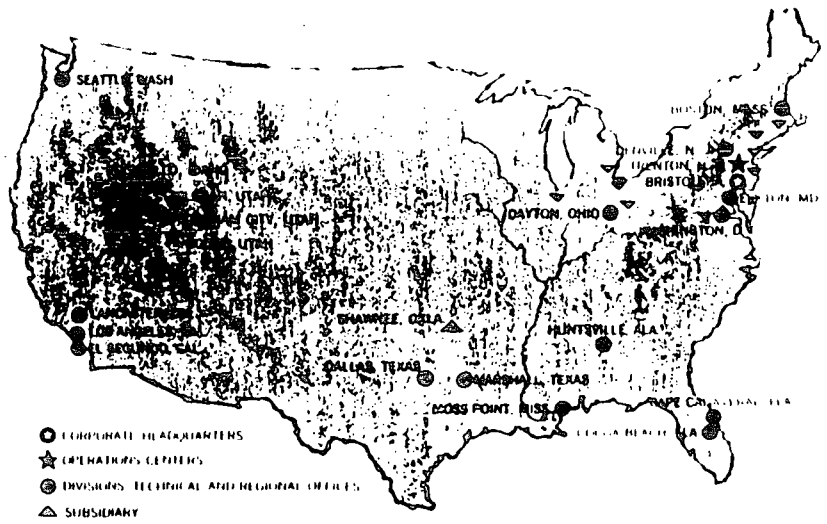
NIKE ZEUS — Thiokol motors propel all three stages to send this missile killer into action instantly.
Prime Contractor: Western Electric and Douglas.

PERSHING—The Pershing has a remarkable record in development.
Prime Contractor: Martin-Marietta.



SURVEYOR — RMD and Elkton Division rockets will provide steering and braking facilities for soft landing on the moon.
Prime Contractor: Hughes.

Recognition and congratulations to Thiokol for their part in the X-15 program were received from President John F. Kennedy during the Harmon Trophy awards.



THIOKOL OPERATIONS AND TECHNICAL SERVICE LOCATIONS

BOSTON, MASS.
Boston Regional Office

DENVILLE, N. J.
Reaction Motors Division

LAKE DENMARK, N. J.
Dynasoar Laboratories

TRENTON, N. J.
Headquarters,
Chemical Operations
Panelyte Industrial
Division

BRISTOL, PA.
Corporate Headquarters
Headquarters,
Specialties Operations
Bristol Division
Reaction Motors
Production Plant

ELKTON, MD.
Elkton Division

WASHINGTON, D. C.
National Electronics
Division
Eastern District Office

HUNTSVILLE, ALA.
Redstone Division
Southeast District Office

MOSS POINT, MISS.
Production Plant
Chemical Operations

CAPE CANAVERAL, FLA.
Technical Service Office

COCOA BEACH, FLA.
Florida Regional Office

MARSHALL, TEXAS
Longhorn Division

DALLAS, TEXAS
Southwest District Office

DAYTON, OHIO
Central District Office

SHAWNEE, OKLA.
Shawnee Industries, Inc.

BRIGHAM CITY, UTAH
Wasatch Division

POCATELLO, IDAHO
Wasatch Division Annex

LOGAN, UTAH
Logan Works

OGDEN, UTAH
Rocket Operations Center

SEATTLE, WASH.
Northwest District Office

LOS ANGELES, CAL.
West Coast Chemical
Division Office
Hunnetrics Division

EL SEGUNDO, CAL.
West Coast Rocket
District Office

LANCASTER, CAL.
Technical Service Office

▼ PANELYTE SALES OFFICES: Brookline, Mass.; Cincinnati, Ohio; Cleveland, Ohio; Detroit, Mich.; Hamden, Conn.; New York, N. Y.; Skokie, Ill.; Trenton, N. J.; Washington, D. C.

U.S. Army Sergeant, one of America's most reliable weapons systems. Powered by solid fuel motors from Thiokol.

THIOKOL PROGRESS

1962 saw Minuteman, America's first solid fueled ICBM, go operational with the Air Force . . . and its first stage move into production at USAF Plant 78 operated by Thiokol. It was the year of the Astronaut with both Carpenter and Schirra, following Glenn's breakthrough flight on February 20, 1962, returned safely from orbit on retro rockets from Thiokol. It was a year of widening opportunity and new market cultivation for our industrial groups. It was a year when research and development projects of the past bore fruit, and when new ventures promising a still brighter future were begun.

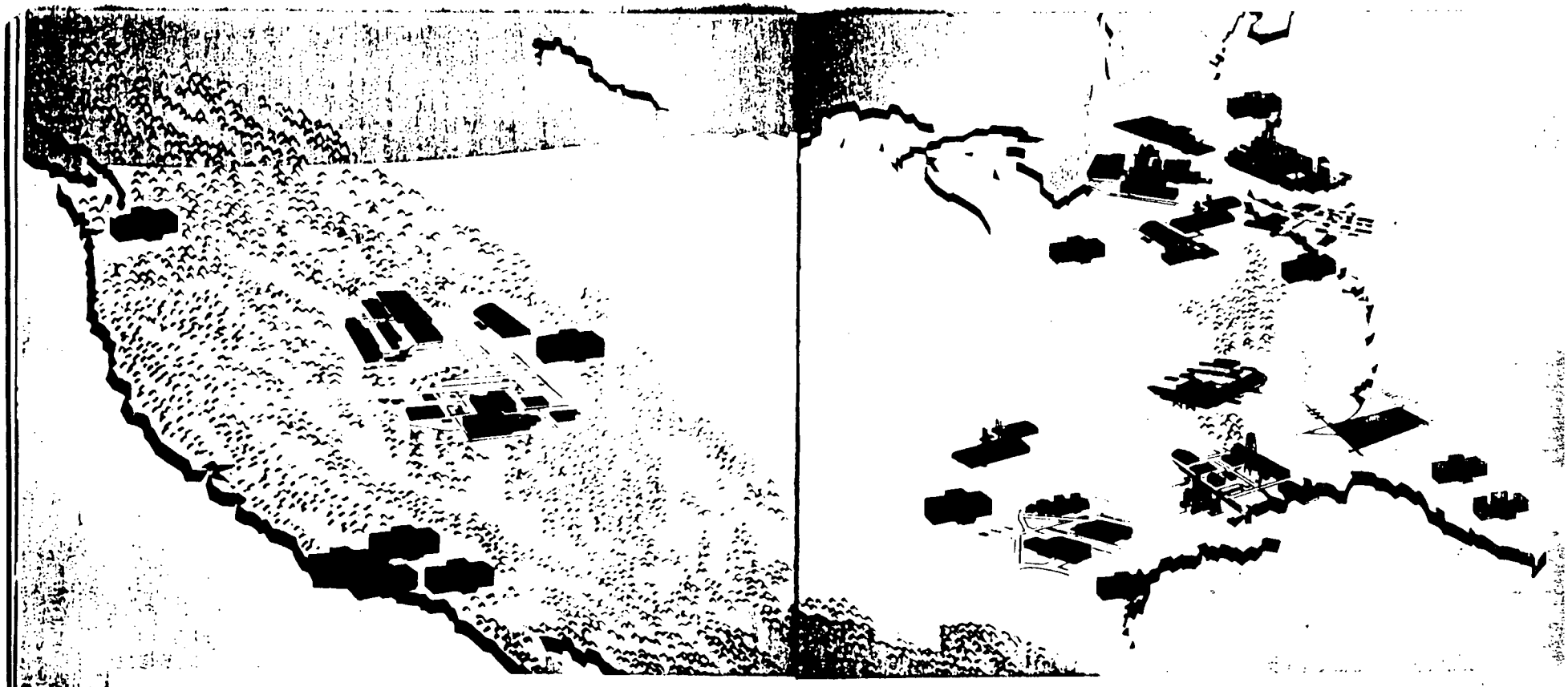
ROCKET OPERATIONS

Thiokol moved strongly ahead on its military assignments, and took equally strong steps toward the conquest of space.

Minuteman was turned over to SAC. Sergeant hit its stride with the Army in the field. The Navy's Bullpup "A" went into mass production. Pershing and Nike Zeus piled up impressive developmental records. Retro rockets proved total reliability in Mercury manned orbital flight. Spherical engines for application in the Surveyor program met all test objectives.

The X-15, repeatedly successful in flight, continued to hit new speed and altitude marks.

Thiokol moved more aggressively toward a stronger position in projected programs for big solid space boosters, while it also designed and developed new ablative materials, new propellants and engines for future space propulsion systems.



THIOKOL OPERATIONS AND TECHNICAL SERVICE LOCATIONS

BOSTON, MASS
Boston Regional Office

DENVILLE, N. J.
Reaction Motors Division

LAKE DENMARK, N. J.
Dynastar Laboratories

TRENTON, N. J.
Headquarters, Chemical Operations
Panelyte Industrial Division

BRISTOL, PA.
Corporate Headquarters
Headquarters, Specialties Operations
Bristol Division
Reaction Motors Production Plant

ELKTON, MD.
Elkton Division

WASHINGTON, D.C.
Eastern District Office

HUNTSVILLE, ALA.
Headquarters, Alpha Division
Alpha Division – Huntsville Plant
Southeast District Office

BRUNSWICK, GA.
Alpha Division – Space Booster Plant

MOSS POINT, MISS.
Production Plant Chemical Operations

CAPE CANAVERAL, FLA.
Technical Service Office

COCOA BEACH, FLA.
Florida Regional Office

MARSHALL, TEXAS
Longhorn Division

DALLAS, TEXAS
Southwest District Office

HOUSTON, TEXAS
Houston Regional Office

DAYTON, OHIO
Central District Office

SHAWNEE, OKLA.
Shawnee Industries, Inc.

BRIGHAM CITY, UTAH
Wasatch Division

POCATELLO, IDAHO
Wasatch Division Annex

LOGAN, UTAH
Logan Works

OGDEN, UTAH
Rocket Operations Center
Astromet Division

SEATTLE, WASH.
Northwest District Office

LOS ANGELES, CAL.
West Coast Chemical Division Office
Humetrics Division

SAN BERNARDINO, CAL.
San Bernardino Regional Office

EL SEGUNDO, CAL.
West Coast Rocket District Office
Panelyte Technical Service Office

LANCASTER, CAL.
Lancaster Regional Office

PANELYTE SALES OFFICES

BROOKLINE, MASS
CAPE CORAL, FLA
CINCINNATI, OHIO
CLEVELAND, OHIO
DETROIT, MICH
HAMDEN, CONN
NEW YORK, N. Y.
ROCHESTER, N. Y.
SKOKIE, ILL.
TRENTON, N. J.
WASHINGTON, D.C.

Thiokol

CHEMICAL CORPORATION

BUILDING SEALANTS

INDUSTRIAL SP

Thiokol
CHEMICAL CORPORATION

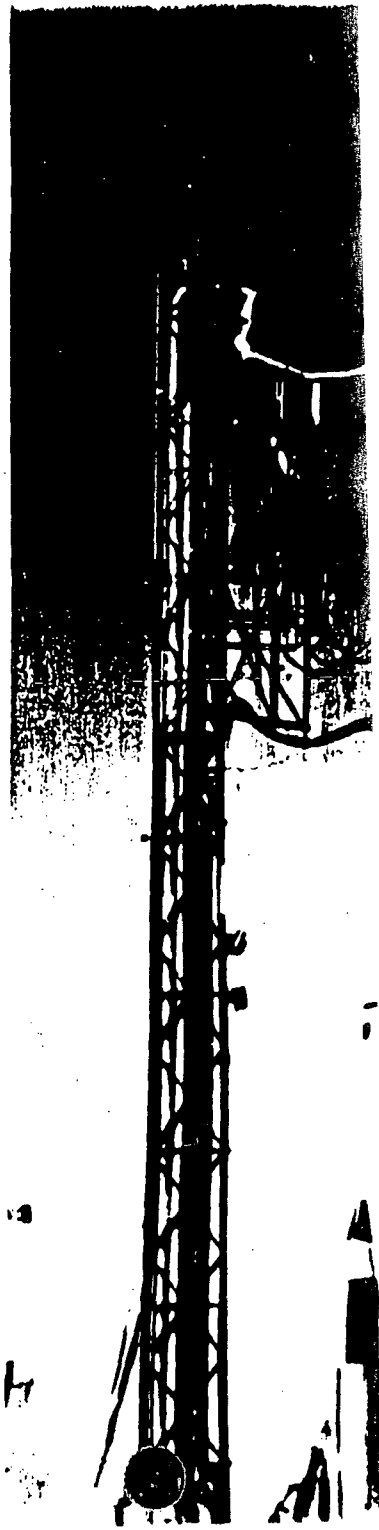
ANNUAL REPORT 1964

Thiokol
CHEMICAL CORPORATION

Our rocket divisions are also supplying engines for space exploration, ullage and retro rockets for lunar vehicles, jettison motors for the Apollo escape system, and "strap on" units to increase the capabilities of the liquid propelled Thor, to name a few. The X-15 powered by the Reaction Motors Division LR99 liquid turbo rocket engine continued to break its own records for manned flight into the upper atmosphere. Over 100 flights have been completed. An improved version of the X-15 with a Thiokol LR99 engine of long duration firing capacity will receive its first tests this spring.

Space Brakes for Gemini. *The two man orbital vehicle, scheduled for flight late this year, will be equipped with solid fueled retro rockets from Thiokol. Four of these compact power packages (shown left) similar to those which proved totally reliable throughout the Mercury program, are being fitted into the capsule's frame. They have a dual role: one, to thrust the capsule safely away from booster rocket in case of launching malfunction; two, to reduce speed of orbiting vehicle for safe re-entry. The Titan II launch rocket for Gemini is fitted with Thiokol safe and arm devices. Its military counterpart is also equipped with Thiokol-made valves.*

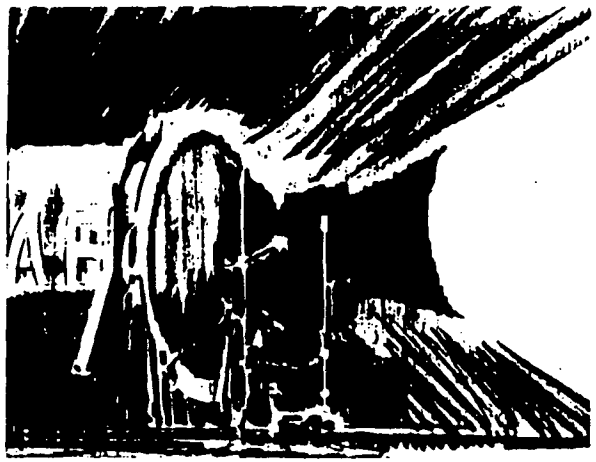
Improved Thor. *Indicative of the growing importance of solids in space is their adaptation to the Thor Standard Launch Vehicle (right), a liquid fueled rocket with a long history of*



These demonstrations, along with further tests of 260-inch diameter engines to follow later this year, will show conclusively the ability of large solid rocket engines to boost heavy payloads into space—proving Thiokol's leadership in producing the world's most powerful rocket engines.

The Reaction Motors Division produced Bullpup engines for the Navy, and is developing controllable liquid engines for space applications. The first such engines will be for the landing of the Surveyor on the moon.

The Elkton Division continues to develop rocket en-



First plateau achieved in big solids program. In December of 1964, the Wasatch Division tested the largest, most powerful solid rocket motor fired up to that date. The 156" diameter powerplant produced 1.4 million pounds of thrust over a two minute burn time. It successfully demonstrated the large motor concept in the first phase of a feasibility study undertaken for the Air Force and NASA. Divisional work on propulsion for Minuteman II also met its objectives as the first advanced model of the solid ICBM was successfully flown in September.

Thrust augmented Thor in flight. One of the most dramatic applications of the Huntsville Division's XM33 solid motor is high booster effect for the Thor launch vehicle shown here as it jettisons its three strapped-on solids. Hunstville has loaded 471 XM33 motors, many of which have already been successfully test flown, ninety-two during 1964, including eight Scout vehicle launchings used for orbiting satellites and for re-entry studies, and the first overland launches of Athena.

zation was effected at the beginning of this year. It is hoped that these changes will enable Panelyte to operate on a profitable basis.

The Logan Division continues to make progress in developing and marketing lightweight tracked vehicles. It has expanded further into the commercial field and future prospects are encouraging.

The Bristol Division has expanded operations into the electro-accoustical field for the Military with encouraging results.

Several years ago the Company initiated the development of a lightweight, compact diesel engine—Dynastar. While the basic work has been completed and a number of engines have been built and successfully tested, further operational testing is required. During the past few months engineering effort on this program has been conducted on a reduced basis, pending completion of a comprehensive re-evaluation of the potential market for this engine. The results of this market survey will not be known until later this year and will, to a large degree, determine the future of this program.

During the year, the Company spent $13,324,753 for new plant and equipment. This was offset in part by $6,244,976 charged for depreciation on facilities in existence.

Employment at the year-end was 9,580 compared to 13,277 a year earlier. The principal reduction in employment was at Rocket Operations with a 31% decrease in personnel.

The losses incurred last year have been eliminated or brought under control. These savings, coupled with increased efficiency and cost reduction programs, should improve the results of operations in future years.

The Directors on October 26, 1964 declared a four percent stock dividend payable December 9, 1964 to stockholders of record November 9, 1964.

At their meeting on June 30, 1964, the Board of Directors elected Mr. J. W. Crosby as Chairman of the Board and Chief Executive Officer. Dr. H. W. Ritchey, formerly Executive Vice President, was named President and R. E. Davis, C. E. Hunter, R. L. Marquardt and F. W. Wilson were elected Vice Presidents.

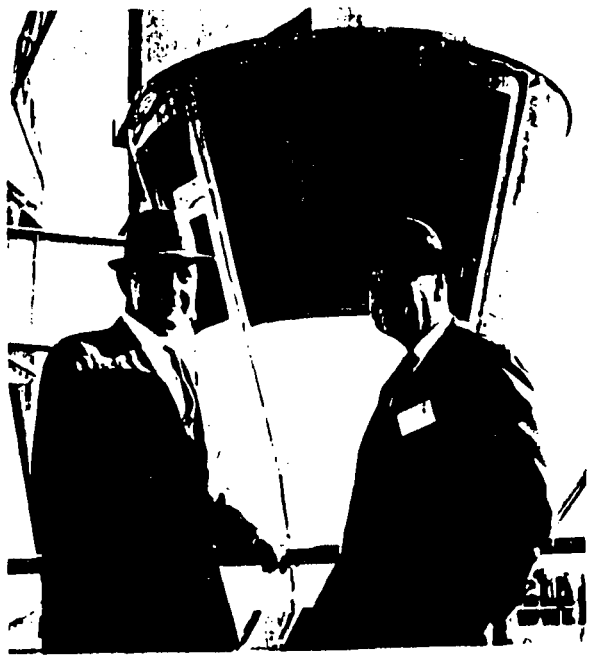
Respectfully submitted,

H. W. Ritchey

Harold W. Ritchey,
President

J. W. Crosby

Joseph W. Crosby,
Chairman of the Board of Directors



Dr. H. W. Ritchey (left) and Mr. J. W. Crosby standing in front of nozzle of 156-inch solid rocket motor before successful test firing of space booster at Brunswick, Georgia.

Thiokol

CHEMICAL CORPORAT

ANNUAL REPOI

1965

A REVIEW OF OPERATIONS

ASTRO-MET DIVISION, OGDEN, UTAH

Astro Met is conducting research, development and production work on sounding rocket vehicles, including payload instrumentation for use in upper atmospheric research. Purchasers of these vehicles include the Atomic Energy Commission, NASA, universities and prime contractors.

The Division provides associated analytical and launch services for its customers and is also doing substantial work for the Defense Atomic Support Agency in the production of launchers for sounding rockets.

ELKTON DIVISION, ELKTON, MARYLAND

Retrograde rockets produced by Elkton continued to serve as "space brakes" for our orbiting astronauts. One such motor made by Elkton will also be used as the prime braking system for the Surveyor spacecraft, programmed for a soft landing on the moon this year. Contracts were received in 1965 for modification of the Surveyor retro motor for use in the Air Force Burner II and NASA improved Delta programs.

Development effort includes work on improved aircraft seat ejection systems, ordnance devices, Apollo Tower Jettison motor, and limited warfare devices for the Army and Air Force.

Production continued on motors for Subroc, the anti-submarine missile, and on various off-the-shelf rocket motors such as Recruit and Apache.

In the area of advanced technology, Elkton is working on improved gas generator propellants and high-performance oxidizers and fuels.

HUNTSVILLE DIVISION, HUNTSVILLE, ALABAMA

Development was initiated for an improved Zeus propulsion system under the Nike X ballistic missile defense program. The Division is also developing air-augmented propulsion systems under contract with the Air Force. These hold great promise for advanced tactical missiles.

Work progressed on controllable solid propellant motors, high energy propellants and area defense propulsion systems.

Motors for launch vehicles such as Athena, Scout, and Thrust Augmented Thor are still being supplied.

LONGHORN DIVISION, MARSHALL, TEXAS

There was a significant increase during the year in the production of pyrotechnic devices and illuminating flares and shells. Further increase in the output of these items is anticipated in 1966. Production of motors for Sergeant, Pershing and Nike Hercules continued.

REACTION MOTORS DIVISION, DENVILLE, NEW JERSEY

A contract for a major development program of the C-1 Common Engine was received from NASA. This engine is planned for use in Advanced Apollo applications. It also has potential use in current NASA and Air Force programs.

The Division produced its 40,000th Bullpup engine this year. Production of packaged liquid propellant engines for use by the Navy and Air Force in Bullpup missiles will continue throughout 1966.

The Surveyor vernier engines were qualified during the year. These will steer the lunar spacecraft, maintain its attitude, and control its rate of descent to the moon's surface.

The Division is providing equipment for altitude test facilities associated with the Apollo and Nerva programs.

Exploratory programs progressed on prepackaged liquid and space propulsion systems, components, materials and high-energy propellants to meet the more stringent demands of future propulsion requirements.

WASATCH DIVISION, BRIGHAM CITY, UTAH

Wasatch continued production of motors for the first stage of the Minuteman II missile.

A contract to demonstrate a 156-inch diameter motor utilizing a fiberglass filament-wound case was received as a follow-on to the 1964 effort which culminated in the successful firing of a million and a half pound thrust motor. The demonstration motor under the current program will be fired in the first half of 1966.

The award of a contract to Hercules Powder Company and Thiokol for development of the first stage of the Poseidon missile was announced

during the year. Poseidon, an advanced fleet ballistic missile, is a follow-on to Polaris.

Development work continued on advanced movable nozzle liquid injection and hot gas thrust vector control systems, controllable solid rocket motors applicable to a new strategic strike missile, high-strength fiberglass cases and high energy propellants.

SPACE BOOSTER DIVISION, BRUNSWICK, GEORGIA

In February, 1965, a 156-inch diameter motor generating 3 million pounds of thrust was successfully tested. At that time, it was the largest solid propellant motor ever fired in the free world. In June, the program was terminated by NASA since sufficient funding was not available to continue, following the failure of the first 260-inch diameter case during hydrostatic proof testing. There is no evidence that there will be adequate funding in the immediate future. Although it is our belief that there is great economic advantage in using large solid boosters for many applications, it appears at this time that the market will not materialize for a period of several years.

The space booster plant has been placed in a stand-by status pending the outcome of efforts to find other work suitable to the particular capabilities of the facilities and location.

CHEMICAL DIVISION, TRENTON, NEW JERSEY; *MOSS POINT, MISSISSIPPI*

Through its research and development efforts over the past several years, the Chemical Division has greatly expanded its technological capabilities, product lines and marketing opportunities. New acrylate and urethane polymers were developed for special markets and are now adding appreciably to sales. These successful efforts achieved in 1965 a 15% increase in sales and in profits, despite greatly increased research and development expenses as well as price reductions on some products.

Research has yielded a new high performance engineering industrial plastic, THIOLON® which is now in pilot plant production. In addition, several new fluorocarbon polymers are now in advanced stages of development. A new plant is under construction at our Moss Point location for the production of these polymers.

In 1964, a Marketing Center was established in the Trenton area. In 1965, the Technical Service function was enlarged and moved to this center for improved support of sales and product development. Research and development facilities were almost doubled in 1965.

Demand for our liquid polymers for applications as sealants in the automotive and building industries remained firm, with some possible expansion anticipated in the coming year. Current technical and marketing efforts are directed toward the mass market for sealants, high performance spandex and plastic fibers, high temperature plastics, and specialty fertilizers. These are all expanding market areas which should enable the Division to broaden its business base and maintain its growth rate.

DYNASTAR LABORATORIES, DOVER, NEW JERSEY

Development work is progressing satisfactorily on the Dynastar lightweight diesel and spark ignition engines. The first prototype 100-horsepower unit has been installed on a U. S. Coast Guard vessel and is now undergoing field trials. Performance of the engine has thus far been excellent. Engines are also being evaluated for industrial applications.

HUMETRICS DIVISION, LOS ANGELES, CALIFORNIA

The Humetrics Division is continuing development work on a family of medical-electronic instruments which can be used by either technicians or physicians in the detection of physiological abnormalities.

One of these instruments, the PhonoCardioScan, a heart sound screening device, has aroused considerable interest. The Chicago Heart Association is currently employing the instrument in a screening test of 10,000 school children in order to identify those who have heart abnormalities requiring professional medical attention.

In March, 1966, an agreement was signed whereby Beckman Instruments, Inc., a leader in the medical-electronic field, will market the PhonoCardioScan and related items of equipment manufactured by the Humetrics Division.

THIOKOL CHEMICAL CORPORATION AND SUBSIDIARIES

Consolidated Statement of Capital in Excess of Par Value

For the Years 1965 and 1964

	1965	1964
Balance at beginning of year	$43,060,383	$40,413,800
Excess of market value over par value of 216,578 shares paid as 4% stock dividend in 1964		2,646,583
Balance at end of year	$43,060,383	$43,060,383

See notes to financial statements

NOTES TO FINANCIAL STATEMENTS

NOTE 1. Costs applicable to cost plus fixed or incentive fee contracts and subcontracts are subject to Government audit and review, and the amount which ultimately will be reimbursed for a substantial portion of such costs has not yet been finally determined. The prices under certain contracts and subcontracts with Government departments are subject under the terms of the contracts to redetermination with these departments. Government contracts and certain other sales are also subject to renegotiation under the Renegotiation Act of 1951. No renegotiation refunds were required for the year ended December 31, 1965, but not all prior years' refunds which may be made under renegotiation proceedings, and under redetermination proceedings, and with respect to redetermination of reimbursability of costs under cost plus fixed or incentive fee contracts and subcontracts, will have a material effect on income or financial position as reported through December 31, 1965.

Amounts expended on cost plus fixed or incentive fee contracts and subcontracts plus anticipated reimbursable overheads and fees but not billed have been included in sales and in amounts receivable on U.S. Government contracts and subcontracts.

NOTE 2. Inventories of U.S. Government contracts and subcontracts are valued at the lower of (1) accumulated costs (material, labor and overhead applicable to each contract) less the estimated average costs over the life of each contract of items delivered or (2) estimated net realization where losses are anticipated, in each case after deduction of unapplied progress payments received. At December 31, 1965 such unapplied progress payments totalled $8,357,467.

NOTE 3. On June 5, 1965 the Company was notified that the contract for the manufacture and test of the 260" space booster engines at its Brunswick, Georgia facility was terminated *in its entirety for the convenience of the Government.* This contract comprised essentially all of the operations of this facility since the commencement of operations in early 1964. The net book value of this facility at December 31, 1965 is approximately $8,000,000 of which $1,950,000 represents the original purchase price of the land. The Company is vigorously pursuing the use of large solid fuel rocket engines for space applications in addition to various alternative programs; however, it is not known at this time, what, if any, programs are or will be available to utilize this facility.

NOTE 4. Included in other assets at December 31, 1965 is $1,210,169 representing cost incurred for engineering development work during the past six years on the Dynastar diesel engine program. The recovery of the development cost depends on sales of the resulting product. It is the Company's intention to amortize these costs by charges to income over a short period of years against revenues produced by this activity. Although management expects to recover this investment and realize a profit, this may not occur

for some time and it is impossible at this time to be certain that the ultimate realization on this program will exceed or equal the development costs already incurred.

NOTE 5. The loan agreements provide that the 5½% promissory notes are due in $900,000 annual installments from July 15, 1966 to 1973 and also provide for optional $900,000 annual prepayments. The loan agreements limit the payment of dividends and other distribution on account of stock under certain circumstances. At December 31, 1965 none of these restrictions apply.

NOTE 6. On April 27, 1965 the stockholders approved a Stock Option Incentive Plan under which 129,432 shares of the authorized but unissued capital stock were made available for issuance to officers and other key employees at a price not less than the fair market value of the shares at the time the options are granted. The options expire five years from the date of grant and are exercisable to the extent of 20% of the total number of shares as of each anniversary date of the granting of the option. The shares initially made available for granting of options under this Plan consist entirely of the shares previously reserved under the old restricted Stock Option Plan.

Options outstanding at December 31, 1965, which were issued under the old restricted Stock Option Plan approved in 1951 and amended in 1960 and 1963, expire five years after grant and become exercisable ratably in the five years succeeding the year of grant. No additional options are to be granted under this Plan and the final option expires in April, 1968.

Shares reserved for granting under these plans amounted to 28,630 at December 31, 1965 and 83,630 at December 31, 1964.

The summary of stock option transactions during the year is as follows:

Options outstanding at December 31, 1964	45,722
Options granted	87,100
Options cancelled	(38,100)
Options outstanding at December 31, 1965	94,722

Options outstanding at December 31, 1965 were as follows:

At $26.25 per share expiring on varying dates from May 1966 to May 1967	6,530
At $24.74 per share expiring by April 1968	1,092
At $11.75 per share expiring by June 1970	87,100
	94,722

There were also six additional options for a total of 6,000 shares at $12.88 per share, expiring on June 28, 1970, outstanding at December 31, 1965. These options were granted to members of the Technical Advisory Board pursuant to action of the Board of Directors and subject to approval of the stockholders at the April 1966 Annual Meeting.

REPORT OF CERTIFIED PUBLIC ACCOUNTANTS

ARTHUR YOUNG & COMPANY

THE BOARD OF DIRECTORS AND STOCKHOLDERS
THIOKOL CHEMICAL CORPORATION

We have examined the accompanying consolidated balance sheet of Thiokol Chemical Corporation and subsidiaries at December 31, 1965 and the related consolidated statements of income and retained earnings and capital in excess of par value and the consolidated statement of source and application of funds for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. It was not practicable to confirm amounts receivable on U. S. Government contracts and subcontracts, but we satisfied ourselves as to their substantial accuracy by other means.

In our opinion, subject to the future operations of the Brunswick, Georgia facility as discussed in Note 3 and the recovery of the deferred engineering development cost referred to in Note 4, the statements mentioned above present fairly the consolidated financial position of Thiokol Chemical Corporation and subsidiaries at December 31, 1965 and the consolidated results of their operations and the source and application of their funds for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year.

Arthur Young & Company

February 18, 1966

Thiokol
CHEMICAL CORPORATION

CHEMICAL CORPORATION

ANNUAL REPORT 1966

REACTION MOTORS DIVISION, DENVILLE, NEW JERSEY

Reaction Motors celebrated its twenty-fifth anniversary in 1966. It was also the tenth anniversary year of the powerplant for the X-15 research aircraft, which continues to set speed records for manned atmospheric flight.

The Division received a contract from North American Aviation, Inc., for development of an advanced packaged liquid engine to power Condor, a new Navy air-to-surface missile. Production continued on packaged liquid rocket engines for the Bullpup air-to-surface missile. In the area of space propulsion technology, development is proceeding on the C-1 Radiamic engine, a compact, multi-purpose engine designed for use in spacecraft attitude control and maneuvering systems. In a related space propulsion accomplishment, vernier engines built by Reaction Motors provided the power for attitude and velocity control aboard the successful Surveyor I spacecraft.

WASATCH DIVISION, BRIGHAM CITY, UTAH

Production of Minuteman first stage motors and development of the first stage of Poseidon continued. Both programs have production schedules extending into the 1970's.

Two major test firings advanced our position in large solid propellant boosters. Under contract with the Air Force, a 120-inch diameter motor, developed and tested by Thiokol, demonstrated a high performance propellant system. A 156-inch diameter motor utilizing a fiber glass reinforced plastic case was successfully tested as a potential stage for future launch systems. Contracts were received from the Air Force for additional work in development of technologies for large solid boosters including thrust vector control systems.

CHEMICAL

CHEMICAL OPERATIONS
TRENTON, NEW JERSEY
MOSS POINT, MISSISSIPPI
COVENTRY, ENGLAND
BURLINGTON, CANADA

The year was marked by record high production levels in nearly all product lines. The production increases, aided by continued improvement in manufacturing efficiency, more than offset the effects of price reductions.

In building construction, the use of LP® polysulfide base sealants increased in joint sealing and weatherproofing applications. Use of compounds in the heavy construction areas – airfields, highways, water-carrying structures – also showed active growth, due mainly to new products developed by the Division's Technical Service and Development Laboratories.

Contributing heavily to sales was the use in the automotive, marine and original equipment markets of products based on Thiokol's polymers and synthetic rubbers. These ranged in application from automotive windshield sealants and transmission seals to abrasion-resistant industrial rollers.

Sales of specialty synthetic elastomers and plasticizers to the rubber industry also increased. The growing variety of applications for the new urethane and polyacrylate rubbers promises continuing growth in that market.

Export sales increased 25% during the year. A high level of construction activity in the United Kingdom, Europe, Canada, Japan and other parts of the world, coupled with the increasing use of LP® polysulfide based building sealants, was largely responsible for this achievement.

A new subsidiary, Thiokol Canada Limited, was established during the year to provide closer and more effective contact with Canadian markets.

Research and development on a new engineering plastic and extruded spandex fiber were carried to an advanced stage. Development work on the fluorocarbon resin line has resulted in new products and the establishment of a new processing unit which began operations early in 1967.

INDUSTRIAL

LOGAN DIVISION, LOGAN, UTAH

In 1966, Logan introduced a new series to its family of tracked vehicles for off-the-road application. Called the JUGGERNAUT™ vehicle its models range in carrying capacity from six to thirty tons. Typical customers for these large vehicles are oil companies, electrical utilities, and geophysical exploration groups.

With the addition of the JUGGERNAUT™ vehicle, there are currently fourteen types in the Thiokol line. Designed for a variety of performance requirements, the vehicles are being used to transport men and equipment over rough terrain, traverse swamps, groom snow slopes for ski resorts, patrol wildlife preserves, service power lines and control mosquitoes.

Sales of the overall line continued to grow both in the United States and abroad. Foreign sales—mostly for use in Europe—accounted for 25% of the Division's revenues. New distributors, added to the domestic team, contributed to improved sales.

Facilities were expanded and modernized during the year for improved efficiency. Manufacturing area and a new painting building were added. Equipment added to the production line eliminated certain subcontracting work on component parts.

PANELYTE INDUSTRIAL DIVISION, TRENTON, NEW JERSEY

The use of automated equipment, reductions in unit labor costs, improved efficiency in the utilization of material and the introduction of a new product line all contributed to a profitable operation in 1966. The new product, ultra-thin copper-clad epoxy-fiber glass laminate, added significantly to sales. Used to manufacture circuit boards for miniaturized electronic applications, the material meets rigid quality control specifications.

This quality laminate joins a broad line of paper, canvas, linen, glass or nylon cloth base laminate materials for general application in the mechanical, electrical and electronic markets. The range of properties offered by these items is as diverse as the base materials: structural strength, rigidity, superior dielectric characteristics, good machinability, [illegible]t and water resistance, and dimensional stability.

Sales activity was accelerated on specialty fabrication of components from laminated sheet, rod and tube and inventories of materials were maintained at levels which assured a more rapid response to customer requirements. As a result of these steps, sales lost by discontinuing certain unprofitable product lines have been recovered.

HUMETRICS DIVISION, LOS ANGELES, CALIFORNIA

The Humetrics Division is currently producing three medical electronic instruments designed to aid physicians and to train medical students in the detection of abnormalities of the heart. After extensive clinical evaluation, one of these, the PhonoCardioScan™ instrument, was approved by the American Heart Association, the Chicago Heart Association and the United States Public Health Service as an acceptable mass screening device for the early detection of heart disease in children. Additional instruments, advanced in concept, are now being developed as complements to the present line. Clinical evaluation of these devices is expected to continue in 1967.

DYNASTAR LABORATORIES, DOVER, NEW JERSEY

1966 marked completion of the major portion of the development of the 100 hp. Dynastar™ diesel engine. A quantity of preproduction prototypes is being manufactured for field service testing. Performance of the compact, light-weight Dynastar™ engine has aroused considerable interest, especially for marine, electro generator, and other industrial applications as well as for military use.

Experimental engines are currently in operational trials with the Coast Guard and the Navy, with another scheduled for delivery to the Air Force. The Coast Guard engine has been in successful operation in a new design boat for over a year.

In 1966, the Company adopted the policy of charging to current operations all expenditures in connection with the development of the Dynastar™ diesel engine. In prior years, such costs [illegible]en deferred

Thiokol
CHEMICAL CORPORATION
Thiokol CHEMICAL CORPORATION

The Widening World of Thiokol

DEFENSE AND SPACE

Under new and continuing contracts, the Aerospace Divisions contributed significantly to vital military and national space programs.

First stage motors for two strategic deterrents

Work on the large first stage propulsion systems for the Minuteman and Poseidon missiles proceeded on schedule. Minuteman is the nation's major operational land-based strategic deterrent weapon. Poseidon is the second generation fleet ballistic missile which will be carried by the Polaris submarines when development is completed.

The Company was selected to develop the rocket motors for the U.S. Army's new surface-to-air defensive missile, SAM D. Production was renewed on the sustainer motors for the Army's Nike Hercules antiaircraft missile and continued for the Navy Subroc antisubmarine missile. The Department of Defense in 1967 announced a limited deployment of the Sentinel antiballistic missile system in which Thiokol will participate through development and production of the Spartan missile propulsion system. These efforts further strengthen the Company's already strong position in defensive missile propulsion.

The requirements of the Vietnam war sharply increased production of pyrotechnic and ordnance devices. Development and demonstration of improved illuminants was also initiated.

Liquid and solid propulsion for space

In the space program, Thiokol provided the propulsion reliability and precision required for several important missions. Both the liquid propellant attitude control engines and solid propellant "braking" retrorockets were supplied for all the Surveyor flights, an unmanned lunar landing program hailed by the press as "perhaps the greatest technological achievement of the space age."

Thiokol helped man move closer to a landing on the moon with the successful launch of the Apollo/Saturn vehicle. Fifteen of the Company's solid propellant rocket motors were used to jettison the escape tower, separate vehicle stages and force liquid propellants to the main engines during flight.

Production of solid propellant Castor and spherical motors was maintained at a high level for an increasing number of space and test vehicles such as Scout, Athena, Thrust Augmented Thor, Thrust Augmented Delta and Burner II.

The Company's environmental measurement capability was broadened during the year by purchase of the Hy-Tel product line. These hydrological instruments, originally created to monitor water and snow conditions in remote areas, are also being adapted to provide data on water pollution levels. Using vehicles and scientific payloads developed by the Company for atmospheric research, Thiokol personnel conducted flight tests for NASA both in this country and abroad.

Technology for advanced propulsion systems

Significant developments during the year included static test firings of 120-inch and 156-inch diameter solid propellant rocket motors with advanced thrust vector control systems, further testing of both liquid and solid air-augmented rocket propulsion systems and demonstrations of a controllable "start-stop-start" solid propellant motor. Several R&D contracts were received to demonstrate propulsion capabilities applicable to Multiple Independent Reentry Vehicles (MIRV's).

A new elastomer, carboxy nitroso rubber, advanced from the laboratory to limited production. This elastomer possesses many desirable properties, such as outstanding chemical resistance, serviceability over a wide temperature range, excellent abrasion resistance and nonflammability in a 100% oxygen atmosphere.

TRANSPORTATION EQUIPMENT AND MATERIALS

Products of the Company filled a variety of customer requirements in this broad market.

Products for automotive design and production

American automotive manufacturers installed windshields and rear windows with sealants based on LP® polysulfide liquid polymers. Design engineers shaped prototypes of tomorrow's models with the aid of molding compounds formulated from these polymers. Suppliers to the industry utilized [illegible] rubbers and

Thiokol
CHEMICAL CORPORATION
Bristol, Pennsylvania 19007

ANNUAL REPORT

Thiokol CHEMICAL CORPORATION 1968

motors were used for an increasing number of launch and test vehicles such as Scout, Athena, Delta, Thrust-Augmented Delta, and Burner II. Thiokol received a contract to develop and produce spherical motors for NASA's Advanced Delta Vehicle, and the Castor IV motor was selected for the Advanced Athena Vehicle.

[ ]Production of pyrotechnic and ordnance items was maintained at a high level throughout the year. The 10 millionth round of illuminating ammunition was produced as part of a continuing program for the Army. Several new illuminant devices were also introduced.

R. A. McElvogue
General Manager
Longhorn Division

H. A. Koch
General Manager
Reaction Motors Division

J. M. Stone
General Manager
Wasatch Division

[ ]Processing techniques developed in the manufacture of solid propellant rocket motors and company-sponsored research led to new business opportunities. Among these were contracts from the Air Force for the qualification of two new flares; from the Army, for the production of military pyrotechnicals; from the Atomic Energy Commission, for the fiberglass reinforcement of a 94-inch diameter steel pipe; and for demonstration of improved munitions concepts, explosives, and materials for nonpropulsion applications.

Other new business awards include the manufacture of valves for the Titan III launch vehicle, precision machining of gas turbine components and projectiles, and the qualification of an improved aircraft pilot escape system.

Completion of the Sprint contract and the Bullpup packaged liquid engine production late in 1967 as well as a sharp drop in funding for liquid propulsion systems resulted in a very substantial decrease in work levels at the Reaction Motors Division. Operations were consolidated, personnel reduced, and additional work secured, such as machining of gas turbine components and projectiles. Efforts are continuing to increase the utilization of this facility.

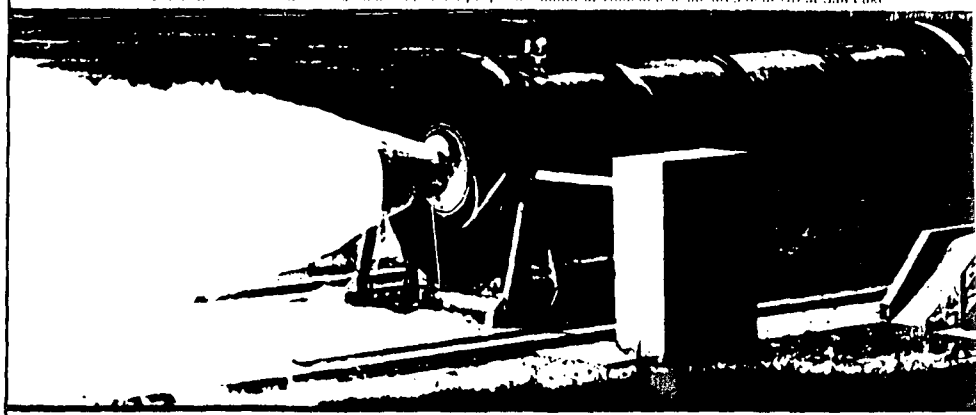
[ ]Continuing advancement in technology was demonstrated during the year. The world's largest segmented fiberglass motor case – 156 inches in diameter, spun from over 34 million miles of fiberglass filament – performed successfully in a test-firing in June. The motor generated in excess of one million pounds of thrust in the two-minute test. Other motor firings confirmed a technological breakthrough in high burning rate solid propellants applicable to future defensive and offensive systems. Fluid-controlled and dual chamber solid propellant motors were successfully tested, yielding valuable technology applicable to Multiple Independent Reentry Vehicle (MIRV) propulsion systems. A significant demonstration of multiple stop-start and thrust modulation of solid propellant motors was also accomplished. These and other technical accomplishments achieved during the year strengthen the company's ability to participate in future aerospace business.

Packaged into fiber tubes completed rounds of illuminating ammunition are readied for shipment.

Solid propellant motors for Pershing and Sergeant missiles travel conveyor line to propellant curing area.

Kinetic studies of atomic species are typical of continued Aerospace research and development activities.

Exhaust roar from a 156-inch diameter solid propellant motor at Thiokol test site area near Great Salt Lake.



First stage motor for the Poseidon fleet ballistic missile moves through manufacturing process

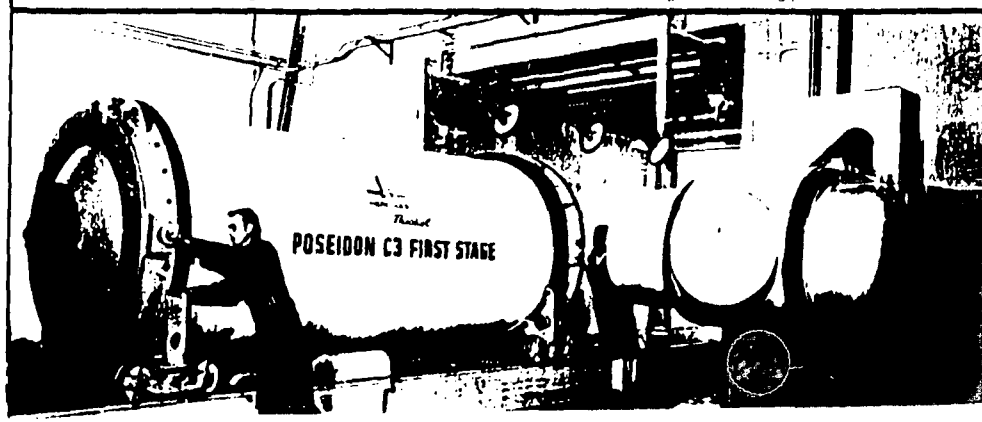


EXHIBIT NO. 13

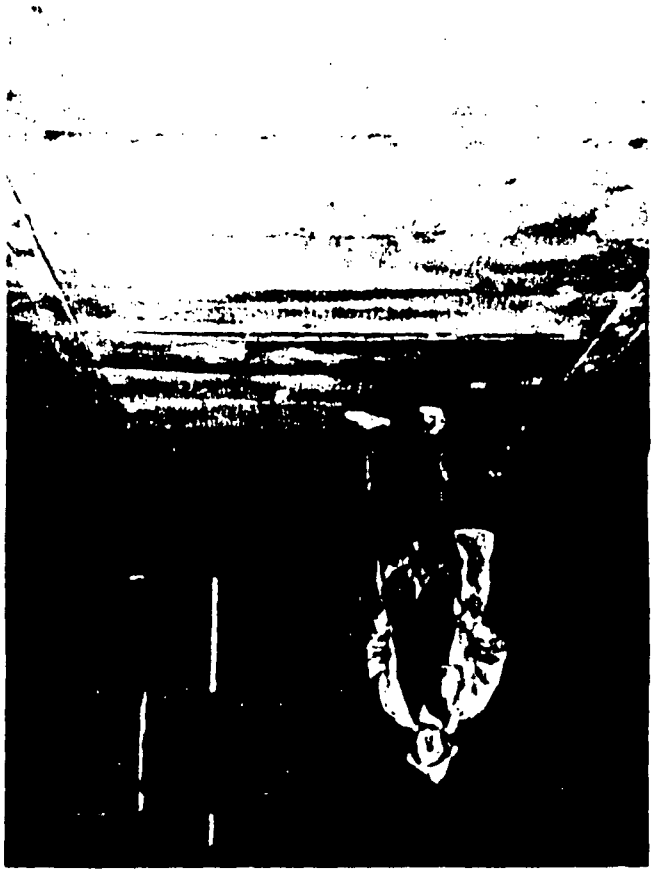


EXHIBIT NO 14

AETNA CASUALTY & SURETY COMPANY

POLICY NO.	DATES OF COVERAGE
4 AL 9300 RRY	59/01/01-60/01/01
4 AL 11000 RRY	60/01/01-61/01/01
4 AL 13600 RRY	61/01/01-62/01/01
4 AL 16000 RRY	62/01/01-63/01/01
4 AL 18400 SR(Y)	63/01/01-64/01/01
4 AL 20700 SR(Y)	64/01/01-65/01/01
4 AL 23600 SR(Y)	65/01/01-66/01/01
04 AL 027300 SR(Y)	66/01/01-67/01/01
04 AL 119000 SR (Y)	67/01/01-68/01/01
04 AL 121380 SR(Y)	68/01/01-69/01/01
04 AL 124200 SR(Y)	69/01/01-70/01/01
04 AL 125900 SR(Y)	70/01/01-71/01/01
04 AL 128010 SRA(Y)	71/01/01-72/05/01
04 AL 131050 SRA(Y)	72/05/01-73/05/01
04 AL 133066 SRA(Y)	73/05/01-74/05/01
04 AL 133113 SRA(Y)	74/05/01-75/05/01
04 AL 243539 SRA	75/05/01-76/05/01
04 AL 243599 SRA	76/05/01-77/05/01
04 AL 247727 SRA	77/05/01-78/05/01
04 AL 251339 SRA	78/05/01-79/05/01
04 GL 1451 SRA	79/05/01-80/05/01
04 GL 1500 SRA	80/05/01-81/05/01
04 GL 55442 SRA	81/05/01-82/05/01
04 GL 237659 SRA	82/05/01-83/05/01
08 AL 4900 RR	57/09/01-58/09/01
08 AL 5310 RR	58/09/01-59/09/01
08 AL 6841 RR	59/09/01-60/09/01
08 AL 9019 RR	60/09/01-61/09/01
08 AL 11316 RRY	61/09/01-62/09/01
08 AL 13760 RRY	62/09/01-63/09/01
08 AL 16223 SR(Y)	63/09/01-64/09/01
08 AL 18031 SR(Y)	64/09/01-65/09/01
08 AL 019651 SR(Y)	65/09/01-66/09/01
08 AL 021787 SR(Y)	66/09/01-67/09/01
08 AL 099572 SR(Y)	67/09/01-68/09/01
08 AL 102386 SR(Y)	68/09/01-69/09/01

RWY 002 1485

EXHIBIT NO. 15

CONTINENTAL CASUALTY COMPANY

POLICY NO.	DATES OF COVERAGE
CCP 743 65 24R	69/09/01-70/09/01
CCP 854 96 74R	70/09/01-72/03/01
CCP 903 29 22R	72/03/01-74/03/01
CCP 988 08 86R	74/03/01-76/03/31
CCP 248 32 47	76/03/31-78/03/31
RDU 997 76 52	60/04/04-63/01/01
RDU 997 78 11	63/01/01-66/01/01
RDU 997 79 71	66/01/01-72/01/01
RDU 805 26 27	72/01/01-73/05/01
RDU 975 93 35	73/05/01-74/05/01

RMY 002 1486

EXHIBIT NO. 16

INTERNATIONAL INSURANCE COMPANY

POLICY NO.	DATES OF COVERAGE
540 310627 8	81/03/31-83/03/31
540 310690 8	83/03/31-86/03/31

EXHIBIT NO. 17

ECRA-2
ECRA

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT
HAZARDOUS SITE MITIGATION ADMINISTRATION
BUREAU OF INDUSTRIAL SITE EVALUATION

ENVIRONMENTAL CLEANUP RESPONSIBILITY ACT (ECRA)

APPLICATION FOR ECRA REVIEW
INITIAL NOTICE

SITE EVALUATION SUBMISSION (SES)

This is the second part of a two-part application submittal and must be submitted within 30 days following public release of the decision to close operations or execution of an agreement of sale or option to purchase.

DATE NOVEMBER 11,1985

NAME OF INDUSTRIAL ESTABLISHMENT MASDEN INDUSTRIES

ADDRESS Corner Stickle Avenue & Elm Street

CITY OR TOWN Rockaway ZIP CODE 07866

MUNICIPALITY Rockaway Boro COUNTY Morris

NAME OF PROPERTY OWNER Joseph S. Klockner

FIRM: KLOCKNER & KLOCKNER

ADDRESS: 164 Franklin Avenue

CITY OR TOWN: Rockaway ZIP CODE: 07866

MUNICIPALITY Rockaway COUNTY Morris

SUBMIT THE ORIGINAL PLUS TWO COPIES OF THE FOLLOWING:

(NOTE: ITEM FOURTEEN (14) REQUIRES THREE COPIES)

9. A scaled site map identifying all areas where hazardous substances or wastes have been or currently are generated, manufactured, refined, transported, treated, stored, handled or disposed, above or below ground.
IS THIS MAP ENCLOSED? ☒ YES (See Appendix # 1) ☐ NO

10. A detailed description of the most recent operations and processes at the industrial establishment organized in the form of a narrative report designed to guide the Department step-by-step through a plant evaluation, with particular emphasis on areas of the process stream where hazardous substances and wastes are generated, manufactured, refined, transported, treated, stored, handled or disposed on site, above or below ground. Also identify any floor drains with their points of discharge, septic systems if applicable, seepage pits and dry wells. Please note that establishments which ceased production prior to December 31, 1983, but are subject to ECRA because of on-going storage beyond that date, must provide details on past operations.

IS THIS REPORT ENCLOSED? ☒ YES (See Appendix # 1) ☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

RWY 002 1488

FOR DEP USE ONLY

Name No. _____

11. A. A description of the types, age (installation date), construction material, capacity, contents, and locations of storage vessels, surface impoundments, landfills, or other types of storage facilities, including drum storage, containing hazardous substances or wastes.

ARE THESE FACILITIES IDENTIFIED ON YOUR SITE MAP OR DESCRIBED IN A NARRATIVE REPORT?
☒ YES (See Appendix # 1) ☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

B. The integrity of all underground tanks which contain hazardous wastes or substances must be verified. This may be accomplished in one of several ways: a) Performance of a satisfactory leak test in conformance with Criterion 329 of the National Fire Protection Association, or; b) Performance of subsurface soil investigation (soil borings and analysis), or; c) Excavate and remove the tank and establish the absence of contamination, or; d) other methods approved by the NJDEP.

ARE THE RESULTS OF THE LEAK DETECTION TEST OR THE SUBSURFACE INVESTIGATION ENCLOSED?
☒ YES (See Appendix # 1) ☐ NO

IF YOU HAVE CHECK "NO", STATE THE REASON(S): _____

12. A complete inventory of hazardous substances and wastes, including description and locations of all hazardous substances or wastes generated, manufactured, refined, transported, treated, stored, handled or disposed on site, above and below ground, and a description of the location, types and quantities of hazardous substances and wastes that will remain on site. (Attach additional sheets if necessary.) Review N.J.A.C. 7:1E, Appendix A and N.J.A.C. 7:26-8 prior to completing to ensure that all defined hazardous materials are included.

MATERIAL	QUANTITY	LOCATION	STORAGE METHOD	TO REMAIN ON SITE (Yes or No)
Methanol	55 gal	Area 5 Wire Forming	55-gal drum	No *
Methylene Chloride	55-100 gal	Area 7 Tube Filling	55-gal drum	No *
Trichlorethylene	55 gal	Area 8 Bulb Sealing	55-gal drum	No *

*Used in production

RWY 002 1489

13. A. A detailed description, date and location on a scaled map of any known spill or discharge of hazardous substances or wastes that occurred during the historical operation of the site and a detailed description of any remedial actions undertaken to handle any spill or discharge of hazardous substances or wastes. (Attach additional sheets if necessary.)

IS THIS INFORMATION ENCLOSED? ☒ YES (See Appendix # 1) ☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

ARE THE SPILLS IDENTIFIED ABOVE INDICATED ON THE SCALED SITE MAP? ☒ YES ☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

13. B. If this facility has an approved Spill Prevention Control and Countermeasure Plan (SPCC), enclose a copy with this submittal.

IS YOUR SPCC PLAN ENCLOSED? ☐ YES (See Appendix # _____)
☒ NO, this facility is not required to have an SPCC plan

14. A. A detailed sampling or other environmental evaluation measurement plan which includes proposed soil, groundwater, surface water, surface water sediment, and air sampling determined appropriate for the site. (This sampling plan must be developed in conformance with ECRA Regulations N.J.A.C. 7:1-3.14 et seq., and Quality Assurance Guidelines as developed by DEP)

ARE THREE COPIES OF THE SAMPLING PLAN ENCLOSED? ☒ YES (See Appendix # 1)
☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

14. B. If the sampling plan includes groundwater sampling and/or the installation of monitoring wells, the applicant must complete a "Request for Hydrogeologic Assessment" form (blank form attached).

IS GROUNDWATER SAMPLING PROPOSED? ☐ YES ☒ NO

IS THE "REQUEST FOR HYDROGEOLOGIC ASSESSMENT" FORM ATTACHED? ☐ YES (See Appendix # _____)
☒ NO

RWY 002 1490

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): The quantity of possible fuel oil leakage and spills would have been small. Sampling proposed now covers the soils around the fuel oil storage tanks.

15. A detailed description of the procedures to be used to decontaminate and/or decommission equipment and buildings involved with the generation, manufacture, refining, transportation, treatment, storage, handling, or disposal of hazardous wastes or substances including the name and location of the transporter, the ultimate disposal facility, and any other organizations involved.

IS THE DETAILED DESCRIPTION ENCLOSED? ☒ YES (See Appendix # 1) ☐ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): _____

16. Copies of all previous soil, groundwater and surface water sampling results, including effluent quality monitoring, conducted at the site of the industrial establishment during the history of ownership/operation by the owner or operator. Also include a detailed description of the location, collection, chain of custody, methodology, analyses, laboratory, quality assurance/quality control procedures, and other factors involved in preparation of the sampling results.

ARE HISTORICAL RESULTS ENCLOSED? ☐ YES (See Appendix # _____) ☒ NO

IF YOU HAVE CHECKED "NO", STATE THE REASON(S): No sampling has been performed or required.

17. List any other information you are submitting or which has been formally requested by this agency:

I hereby certify that the information furnished on this application and any attachments is true. I am aware that false swearing is a crime in this State. I am cognizant that providing false information is a violation under ECRA and that I may be personally liable for penalties up to $25,000 per day.

_____
Signature

_____
Date

Joseph S. Klockner
Name (Print or Type)

Partner
Title

RWY 1491

APPENDIX 1

9. SITE MAP

The overall property is shown in Figure 1, Property Map.

Locations where hazardous substances are stored are shown in Figure 2, Masden Industries Site Plan.

10. DETAILED DESCRIPTION OF OPERATIONS AND PROCESSES

Masden Industries manufactures Christmas tree lights and specialized batteries and fuses in its 9600 sq ft portion of the Klockner & Klockner building. The firm also uses the adjacent outdoor paved area for storage and parking.

Three underground fuel oil tanks are also included under this Site Evaluation Submittal for the Masden Industries industrial establishment.

For purposes of this detailed description, Masden's operations are assigned area numbers as shown on the Site Plan, Figure 2. The operations conducted in each area are described as follows:

Area 1, Graphite Machining. Operations are drilling and machining of graphite forms that are shipped in as raw materials. There are no liquid process streams or floor drains.

Area 2, Glass Powder Pressing. Operations are pressing glass powder into pills. There are no liquid process streams or floor drains.

Area 3, Glass Pill Oven, is for heating glass pills to fuse together the pressed particles. There are no liquid process streams or floor drains.

Area 4, Machine Shop, is equipped with lathes, drill presses and milling machines that use no lubricating fluids. There are no liquid process streams or flow drains.

Area 5, Wire Forming operations are forming and cutting wire from coils to form filaments. Lubricating oil is occasionally used. Oil drips as may infrequently occur are cleaned up with hand wipes that are disposed of as solid waste. Methanol is occasionally used for cleaning, approximately one 55-gallon drum per year. There are no liquid process streams or floor drains.

Area 6, Heat Treatment & Glass Sealing. Electric ovens are used to heat glass in an atmosphere of N_2 or H_2, or a mixture of N_2 and H_2. There are no liquid process streams or floor drains.

Area 7, Tube Filling. Glass tubes are filled with methylene chloride, sugar and sodium metaphosphate. There are no liquid waste streams or floor drains. Occasional drips are cleaned up with hand wipes that are disposed of as solid waste. One to two 55-gallon drums of methylene chloride are maintained in this area.

Area 8, Bulb Sealing. Light bulbs are finished by heat sealing using propane and oxygen burners. One 55-gallon drum of trichlorethylene is maintained in this area for cleaning the finished bulbs. Occasional drips are cleaned up with hand wipes that are disposed of as solid waste. There are no floor drains.

Area 9, Glass Ampules. A glass working machine uses propane, H_2 and oxygen to form ampules that are filled with fluoroboric acid as a battery electrolyte. One 5-gallon container of acid is maintained in this area. Occasional drips are cleaned up with hand wipes that are disposed of as solid waste. There are no liquid waste streams and no floor drains.

Area 10, Shipping and Receiving. There are no liquid wastes or floor drains in this area.

Area 11, Quality Control. One 2-gallon container of limonene is maintained as a refractive index standard for quality control. Occasional drips are cleaned up with hand wipes that are disposed of as solid waste. There are no liquid wastes or floor drains.

Area 12, Office. There are no process waste streams or floor drains in this area.

11. STORAGE FACILITIES DESCRIPTIONS

A. Descriptions

Raw materials and cleaning chemicals are stored indoors, at the production areas where the materials are used, as described in Section 10.

Empty drums, for return to the chemical suppliers, are stored in a portion of the outdoor paved area north and east of the building. The empty drum storage location is shown on the Site Plan, Figure 2. No more than 4 to 6 empty drums are allowed to accumulate on site.

General storage of used equipment is maintained in the paved outdoor area east of the building occupied by Masden Industries. This area is shown on the Site Plan, Figure 2.

Three underground #2 fuel oil storage tanks are part of the building's owner maintained central heating system that services other tenants, as well as Masden. As no site evaluation submittal is required for the central heating system, the oil storage tanks descriptions are presented here, in the submittal for Masden Industries. The tanks are as follows:

	Tank No. 1	Tank No. 2	Tank No. 3
Product Stored	#2 Oil	#2 Oil	#2 Oil
Capacity, gallons	1,000	5,000	1,000
Tank Construction	Steel	Steel	Steel
Age	Undetermined	Undetermined	Undetermined
Tank Top to Grade	24"	24"	24"

Locations of the underground oil storage tanks are shown in Figure 2, Site Plan.

B. Underground Tank Tests

The three underground oil storage tanks were tested on April 23, 1985, by Tank & Line Compliance using the Petro-Tite method whereby a hydrostatic head is applied to a full tank and indicated leakage is determined from change in liquid level in the hydrostatic column.

Based on National Fire Protection Association,Standard 329, Tank #1 was determined to be tight; Tank #2 showed possible leakage of 0.115 to 0.215 gph; and Tank #3 showed possible leakage of 0.020 to 0.121 gph.

Repair work consisting of replacement of a gasket on Tank #2 and piping repair at Tank #3 were performed. These tanks were retested by Fairfield Maintenance, Inc., on May 10, 1985, using the Petro-Tite method. Tank #3 was found to be tight and Tank #2 to have a possible leakage in excess of the National Fire Protection Association, Stardard 329.

Test report summaries by Tank & Line Compliance and by Fairfield Maintenance, Inc., are included under Section 16, hereinafter.

12. INVENTORY OF HAZARDOUS SUBSTANCES

See ECRA-2 Form.

13. DETAILED DESCRIPTION OF SPILLS OR DISCHARGES OF HAZARDOUS SUBSTANCES OR WASTES

The only known or suspected spills or discharges are associated with the underground storage tanks for No. 2 fuel oil.

Tank #1 has been tested and found to be tight in accordance with NFPA Standard 329. However, there has been evident spillage of oil due to overfilling the tank, probably over a number of years.

Tank #2 has been inactive, but full for four years since the main boiler was converted to use gas. There has not been a significant loss of oil from the tank in the four years that it has been inactive. However, the tank tests performed in April and May 1985 indicate possible leakage.

Tank #3 was found to have possibility for leakage when tested in April 1985. After repairs to piping connections were made the tank was tested in May 1985 and found to be tight.

Locations of the underground tanks are shown in Figure 2.

EXHIBIT NO. 18

DRAFT

SAMPLING PLAN RESULTS
MASDEN INDUSTRIES
MULTIFORM METALS DIVISION
ECRA CASE #85551

Prepared for

KLOCKNER AND KLOCKNER, INC.
164 Franklin Avenue
Rockaway, New Jersey 07866

Prepared by

MORETRENCH ENVIRONMENTAL SERVICES, INC.
100 Stickle Avenue
Rockaway, New Jersey 07866

October 3, 1987

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Appendix A - Well Logs, Completion Reports, Survey Data

Appendix B - Lab Reports - Drill Cuttings & Fluids

Appendix C - Manifest - Tank washings

Appendix D - Groundwater Lab Reports (2 rounds) NOT INCLUDED IN DRAFT

Appendix E - Lab Reports - Tank Sampling

RWY 002 1500

F.D.#64:KLOCKNER.110

EXECUTIVE SUMMARY

This report presents the results of sampling at the Klockner and Klockner property located at the northeast corner of the intersection of Stickle Avenue and Elm Street in the Borough of Rockaway, Morris County, New Jersey. Sampling activities in conformance with ECRA were undertaken in accordance with the Revised Sampling Plan dated November 1986, prepared by Moretrench Environmental Services, Inc. (MES) and approved by NJDEP.

The purpose of the sampling activities was to evaluate the groundwater quality and to determine the integrity of an on-site storm water conveyance system.

Six monitoring wells were installed on-site. Three wells were shallow, installed to a depth of about 20 to 25 feet deep. Three deeper wells were installed below a silt/clay layer, and screened in the upper 10 feet of the lower aquifer zones.

Two rounds of groundwater sampling were conducted. The first sampling was performed on the six on-site wells, during the period of 6/30/87 through 7/2/87. The second round of sampling was performed during the period of 8/7/87 through 8/10/87. Included in this round were two off-site NJDEP wells, SAI-5 and SAI-7, which are upgradient and downgradient, respectively, of the Klockner and Klockner site.

The analytical results from the two rounds of samplings indicate that elevated levels of volatile organic compounds are present in both the shallow and deeper groundwater zones beneath the site.

During the course of monitoring well installation a fifth underground tank was discovered. This tank was removed and was found to be in good condition. Post-excavation sampling verified that the soils below the tank were clean.

The integrity of the catch basin system was tested and was found to be leaking. Removal and cleanup of soils associated with the storm water conveyance system will be addressed in the site Cleanup Plan to be prepared.

Since this site is also included in a CERCLA (Superfund) investigation, a meeting between all concerned parties to discuss how the site groundwater contamination should be addressed under a Cleanup Plan is proposed.

SAMPLING ACTIVITIES

INTRODUCTION

Moretrench Environmental Services (MES) has been retained by Klockner and Klockner, Inc., to undertake the administrative and technical tasks associated with compliance with the Environmental Cleanup Responsibility Act (ECRA) at the Klockner and Klockner property located at the northeast corner of Stickle Avenue and Elm Street, Rockaway Borough, Morris County, New Jersey. Ground/Water Technology, Inc. (G/WT) which had prepared all past technical documents associated with this ECRA case is an affiliate company of MES. The location of the site is shown on Figure 1.

Klockner and Klockner is owner and landlord of the property. The site has been separated into two ECRA cases according to current tenants: Masden Industries, Multiform Metals Division (ECRA Case #85551), the subject of the revised sampling plan, and Service Metal Fabricating (ECRA Case #85552).

Service Metal Fabricating was inspected on 12/23/85. A letter was received from NJDEP dated 1/6/86 authorizing submittal of a Negative Declaration for this company. A Negative Declaration has not yet been submitted since transfer of the property is contingent upon an approved Cleanup Plan for the remainder of the site.

The original sampling plan for Masden Industries was prepared as part of the Site Evaluation Submission, dated 11/11/85. The original plan was revised on 12/3/85, after receipt of comments from NJDEP-ISEE in a letter dated 11/21/85. That sampling plan was implemented and four underground storage tanks (tanks #1, #2, #3, and #4) were removed. Contaminated soils associated with those tanks were excavated and disposed of and post excavation samples were collected to verify that soils remaining in place were within acceptable cleanup guidelines. Results of the implementation of the 12/3/85 sampling plan were presented in a Revised Sampling Plan dated November 1986.

The purpose of that revised sampling plan was to 1) present G/WT's technical approach to investigate the potential for groundwater contamination resulting from the volatile organics found present in tank #4, and 2) to investigate the potential for site contamination resulting from petroleum hydrocarbons and volatile organics found in an on-site storm water catch basin. The Revised Sampling Plan of November 1986 was approved with conditions by NJDEP by letter dated March 5, 1987. This report summarizes the sampling results from these investigation activities.

Activities were performed in three areas of concern:

- Groundwater quality
- Catch Basin/Storm Water Conveyance System
- Tank #5 (found during monitoring well installation)

RWY 002 1504

Because the site is also included in a CERCLA investigation, a meeting between all concerned parties to discuss groundwater cleanup requirements prior to preparation of a cleanup plan for submittal is necessary.

GROUNDWATER QUALITY

WELL INSTALLATION

Six monitoring wells were installed to investigate groundwater quality and flow direction. Well locations were approved by the NJDEP case geologist, Mr. Ted Hayes during a site visit. The locations of wells MW1D and MW3S were changed from the November 1986 sampling plan to correspond with locations chosen by Mr. Hayes.

The three shallow wells extend down to the top of a 10-15 foot thick silty clay/clayey silt layer which was found to be between 20 to 25 feet deep and was continuous over the area bounded by the site monitoring wells. The shallow wells were constructed of 4-inch diameter, threaded flush-joint PVC with 15 feet of 0.010-inch slotted screen. Soil samples were collected from the shallow wells on 5-foot centers to determine stratigraphy and select screened intervals.

The three deep wells were installed to a depth of ten feet below the bottom of the silt/clay layer. They were also constructed of 4-inch PVC. A ten foot section of 0.010-inch slotted screen was

placed below the bottom of the silt/clay layer. Soil samples were collected on 5 foot-depth increments from wells MW1D and MW3D and on a continuous basis from well MW2D to determine stratigraphy and select screened intervals.

All six wells were filtered with a uniform medium sand to approximately 2 feet above top of screen. A bentonite pellet seal was then placed on top of filter sand and the remainder of the hole was grouted with a bentonite-cement grout to ground surface. The top of the wells are protected with a locking steel casing. Where wells were installed in traffic areas the surface protection was placed flush with ground surface. Monitoring well details are shown on Figures 2,3,4, and 5. Logs of each monitoring well and well completion reports are attached as Appendix A. Reference elevations and well locations were surveyed by Donald H. Stires Associates of Somerville, New Jersey. Their report is also included in Appendix A.

Drilling fluids generated during well installation were collected and shipped to the Parsippany/Troy Hills Waste Water Treatment Plant for disposal. Drill cuttings were placed into drums. Samples were analyzed for EP Toxicity and all test results were reported as "undetected". The drill cuttings were disposed offsite.

Copies of the analytical testing results on the drill fluids and drill cuttings are attached as Appendix B.

GROUNDWATER SAMPLING

The first round of groundwater samples were collected from the six on-site wells during the period of 6/30/87 through 7/2/87. After water levels were recorded, three well volumes were then purged from each of the wells using a stainless steel submersible pump. A laboratory cleaned dedicated bailer was used to collect the sample from each well for analyses. Measurements of pH, specific conductance, and temperature were recorded in the field. The samples from all six wells were sent to ICM Laboratory in Randolph, New Jersey for analyses. ICM is a certified NJDEP Laboratory (ID#14116).

Based on the detection of volatile organic compounds in both the shallow and deep wells on site during the first round of sampling, a request was made for access to NJDEP monitoring wells, SAI-5 and SAI-7, during the second sampling round. SAI-5 is located upgradient and SAI-7 downgradient of the Klockner and Klockner property.

The second round of sampling took place on 8/7/87 and 8/10/87. Sampling of the two NJDEP wells was performed first. Mr. Bob Gallagher of NJDEP was on site to provide access to those wells and monitor the sampling procedures. Due to difficulty in removing the cap from well SAI-7, the outer protective casing and

the threaded stainless steel cap had to be cut off with a torch to provide access to the well. The outer casing was welded together after sampling and the well was supplied with a plastic well seal replacing the threaded stainless steel cap. As a result of the delay in sampling well SAI-7, the sampling of the remaining wells was not completed until 8/10/87. The samples were sent to ICM Laboratory in Randolph, New Jersey for analyses.

Catch Basin/Storm Water Convevance System

Because volatile organic compounds and petroleum hydrocarbons were detected in catch basin sediments during the original sampling plan implementation, the potential for possible leakage from this system causing contamination of soils below was investigated. The revised sampling plan proposed testing the integrity of the system. In order to perform this integrity test, the 15-inch concrete storm sewer was plugged with a mechanical packer at the downstream catch basin location. The storm sewer system was then filled with water and the level below the surface was measured. All water had leaked out of the system by the following morning (about 17 hours later).

No further actions regarding the system were undertaken. Cleanup of soils in this area will be addressed in the site cleanup plan.

Underground Tank #5

During the course of installation of well MW3S, an underground storage tank was discovered. The 550-gallon capacity tank contained about 20 gallons of gasoline. The tank washings and gasoline were transported to the E.I. Dupont Chambers Works facility in Deepwater, New Jersey for disposal. A copy of the manifest supporting this disposal is attached as Appendix C.

The excavation was screened using an OVA. No contamination was detected. Six post excavation soil samples were collected from the bottom of the excavation and were sent to ICM laboratory for analyses.

The tank excavation was backfilled with clean fill and the monitoring well installation was accomplished.

DISCUSSION OF RESULTS

Groundwater Quality

Shallow well samples were analyzed for petroleum hydrocarbons, volatile organics plus 15 peaks, base/neutral compounds plus 15 peaks and priority pollutant metals. The deep well samples were tested for volatile organics plus 15 peaks only. Prior to sampling, a request was made in writing to NJDEP to modify the sampling parameters suggested in the sampling plan approval letter of March 5, 1987. Approval was given to eliminate acid extractibles plus 10 peaks. Analytical laboratory deliverables are attached as Appendix D. The results of the analyses are summarized in Tables 1 and 1A.

Analytical laboratory deliverables of the second round of sampling are also included in Appendix D. The results are shown on Tables 1 and 1A for comparison with the first round results.

Water table elevations are summarized in Table 2. Water levels were not measured during the first round of sampling, therefore, a second set of water levels were taken on September 29, 1987. Water levels in the shallow upper aquifer are on the order of ten feet higher than those in the deeper aquifer. This is explained by the presence of a 10-15 foot thick clay layer separating the shallow and deep aquifer zones beneath the site. Groundwater

Table 1
Summary of Groundwater Sampling Results
Shallow Monitoring Wells

PARAMETERS		MW1S (6/30/87)	MW1S (8/7/87)	MW2S (6/30/87)	MW2S (8/7/87)	MW3S (7/2/87)	MW3S (8/7/87)
VOLATILE ORGANIC COMPOUNDS (ppb)							
Trans-1,2-dichloroethylene		130	43	51	97	N.D.	N.D.
Trichloroethylene		230	78	100	280	10	15
Tetrachloroethylene		N.D.	N.D.	N.D.	28	50	82
Total		382	121	151	405	60	97
BASE/NEUTRALS + 15		N.D.	*	N.D.	*	N.D.	*
PRIORITY POLLUTANT METALS (ppm)	Groundwater Standards						
Aresenic	(0.05)	0.007	N.D.	0.014	N.D.	0.014	N.D.
Chromium	(0.05)	0.009	0.014	0.028	0.02	0.019	N.D.
Copper	(2.0)	0.04	0.012	0.07	0.025	0.04	N.D.
Lead	(0.05)	0.023	0.015	0.047	0.025	0.019	N.D.
Zinc	(5.0)	0.09	0.07	0.017	0.08	0.14	0.04
Nickel	None	N.D.	0.011	N.D	0.16	N.D.	N.D.
PETROLEUM HYDROCARBONS		N.D.	*	N.D.	*	N.D.	*
FIELD MEASUREMENTS							
ph		8.8	*	8.8	*	*	*
Specific Conductance (umhos/cm)		496	*	193	*	*	*
Temperature (°C)		11.3	*	17	*	*	*

* Parameter Not Tested for
N.D. Not detected
** Identified but below detection limit

field & trip blanks ?

F.D. 64:110A

RWY 002 1511

Table 1A
Summary of Groundwater Sampling Results
Deep Monitoring Wells

PARAMETERS	Groundwater Standards	MW1D (6/30/87)	MW1D (8/10/87)	MW2D (6/30/87)	MW2D (8/7/87)	MD3D (7/1/87)	MD3D (8/10/87)	SAI-5 (8/7/87)	SAI-7 (8/7/87)
VOLATILE ORGANIC COMPOUNDS (ppb)									
Trans-1, 2-dichloroethylene		ND	ND	20	150	ND	ND	ND	3**
Trichloroethylene		23	14	120	730	180	41	ND	170
Tetrachloroethylene		ND	6	ND	ND	ND	ND	ND	ND
Total		23	20	140	880	180	41	0	170
BASE/NEUTRALS + 15		*	*	*	*	*	*	*	*
PRIORITY POLLUTANT METALS (ppm)									
Aresenic	(0.05)	*	*	*	*	*	*	*	*
Chromium	(0.05)	*	*	*	*	*	*	*	*
Copper	(2.0)	*	*	*	*	*	*	*	*
Lead	(0.05)	*	*	*	*	*	*	*	*
Zinc	(5.0)	*	*	*	*	*	*	*	*
Nickel	None	*	*	*	*	*	*	*	*
PETROLEUM HYDROCARBONS		*	*	*	*	*	*	*	*
FIELD MEASUREMENTS									
pH		8.6	7.3	8.5	*	7.6	7.9	8.6	9.4
Specific Conductance (umhos/cm)		472	541	367	*	575	486	638	365
Temperature (°C)		20	21.8	17.2	*	17.3	23.9	18.4	17.1

*Parameter not tested for
N.D. Not detected
** Identified but below detection limit

field blnk

F D 64:110A

RMY 002 1512

TABLE 2

SUMMARY OF WATER TABLE ELEVATION DATA

Well No.	Reference Elevation (ft)*	Water Table Elevation August 7, 1987	Water Table Elevation September 29, 1987
MW1S	523.40	510.19	510.51
MW1D	519.30	501.03	501.63
MW2S	525.29	510.46	510.78
MW2D	525.60	500.90	501.53
MW3S	524.71	510.51	510.80
MW3D	525.33	500.81	501.46
SAI-5	532.54	501.67	502.25
SAI-6	534.09	512.95	NM
SAI-7	526.37	500.95	501.85

* Reference elevations taken on the north side of the top of the PVC riser pipe.

NM = Not measured

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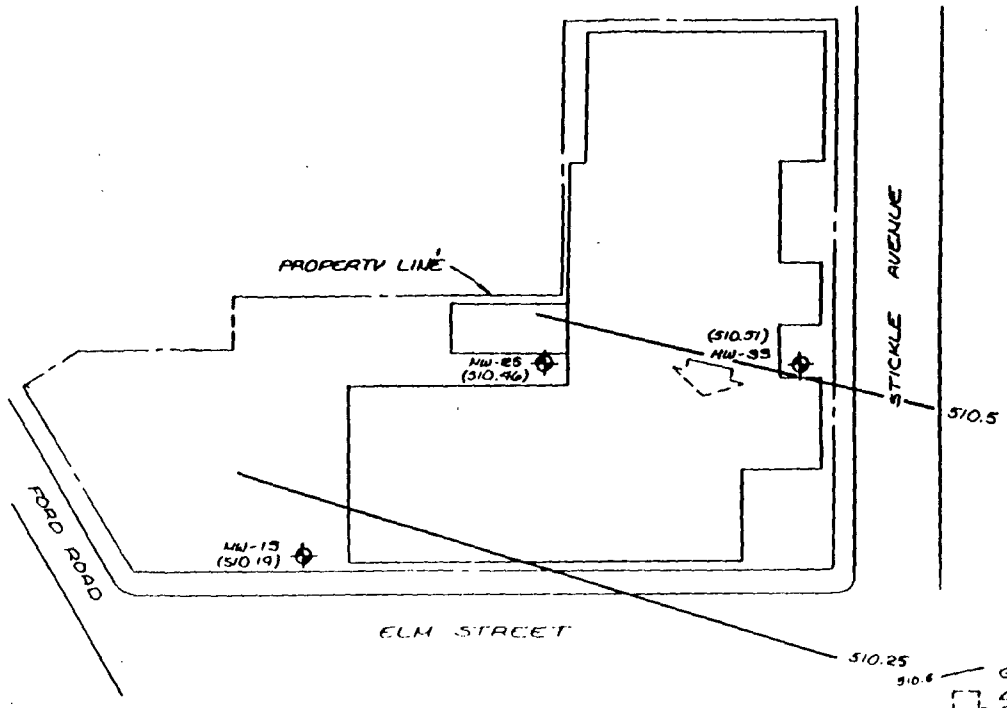
RWY 002 1513

contours of the shallow aquifer are shown on Figures 6 and 7. Flow direction in the shallow aquifer is to the northwest, away from the municipal well field.

Groundwater contours of the deeper aquifer are shown on Figures 8 and 9. Flow direction in the deeper zone conforms with water levels measured in the two NJDEP wells and is toward the south. The gradient in the deeper aquifer is approximately 0.004 ft/ft.

Two groundwater flow regimes were identified on the basis of groundwater contours and stratigraphic data. The shallow system flows from a southeast to northwest direction above a 10-15 foot thick clay/silt layer identified during the monitoring well installations. Analytical results of groundwater samples collected from monitoring wells screened within this flow regime indicate that contamination is migrating on-site at levels ranging from 60-100 ppb, total volatile organics. Elevated concentratins of volatile organics in the downgradient shallow wells are probably attributable to two on-site sources, namely the waste oil tank (Tank #4) and catch basin/storm sewer line along the northern part of the building. The waste oil tank and surrounding soils have been removed and, therefore, eliminated as a future source. Proposed cleanup of the catch basin system and effected soils is discussed in the following section.

The deeper aquifer, which is monitored by MW1D, MW2D, MW3D, SAI-5, and SAI-7, also shows volatile organic contamination. The exception to this is the upgradient NJDEP well, SAI-5, where no



KLOCKNER & KLOCKNER

ROCKAWAY NEW JERSEY

SHALLOW GROUNDWATER CONTOUR MAP

SAMPLING ROUND 2: AUGUST 7 - 10, 1987

FIGURE 6

DRAWN B. SPADY

SCALE 1"=60'

DATE 9/8/87

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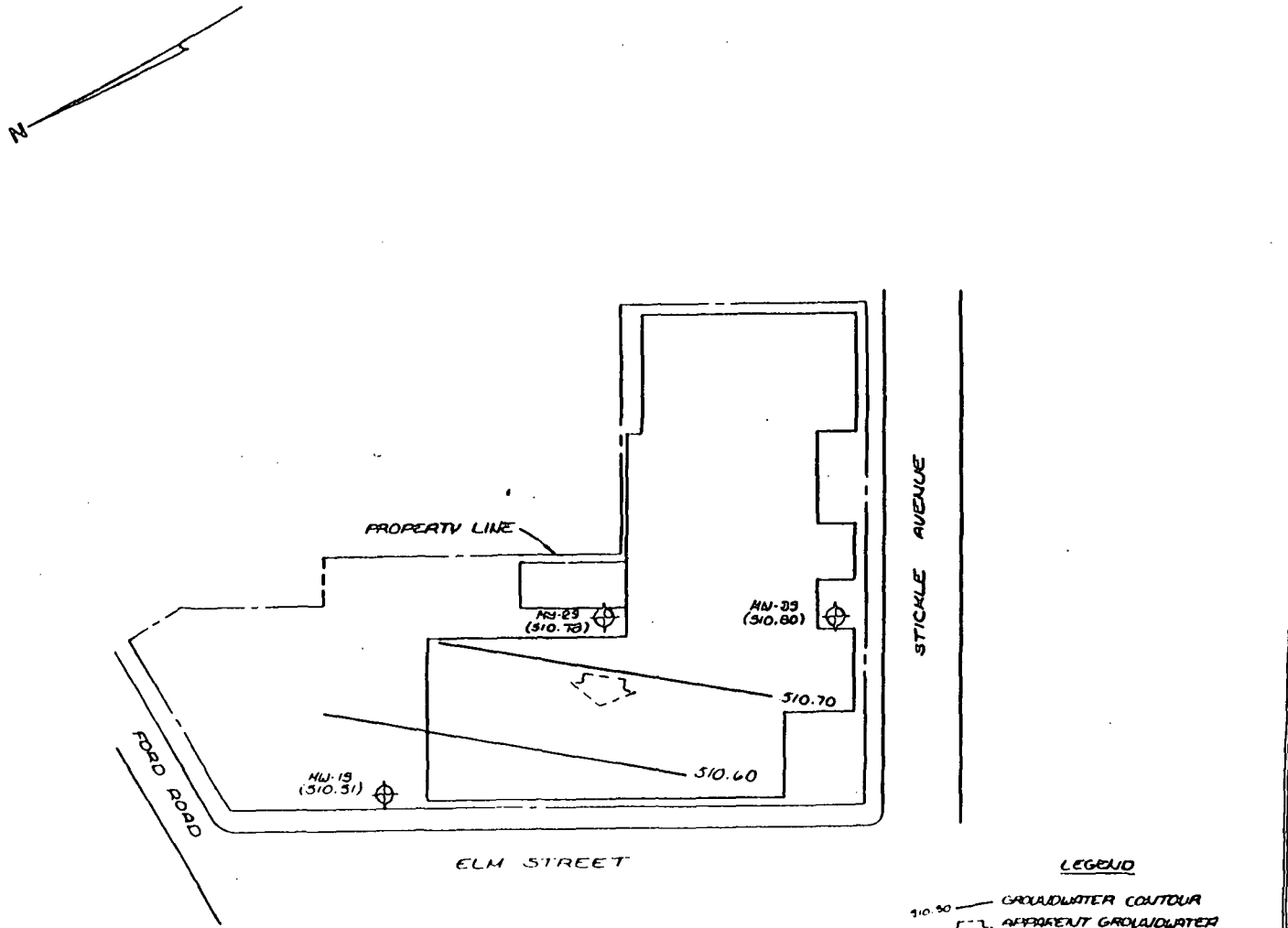
ROCKAWAY NEW JERSEY



LEGEND

310.50 — GROUNDWATER CONTOUR

APPARENT GROUNDWATER FLOW DIRECTION

(310.35) ⊕ MES MONITORING WELL WITH GROUNDWATER ELEVATION IN FEET (MSL)

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ROCKAWAY NEW JERSEY

SHALLOW GROUNDWATER CONTOUR MAP

SEPTEMBER 20, 1007

FIGURE 7

DRAWN D. CRADY

DESIG RLCB

DATE 9/20/07

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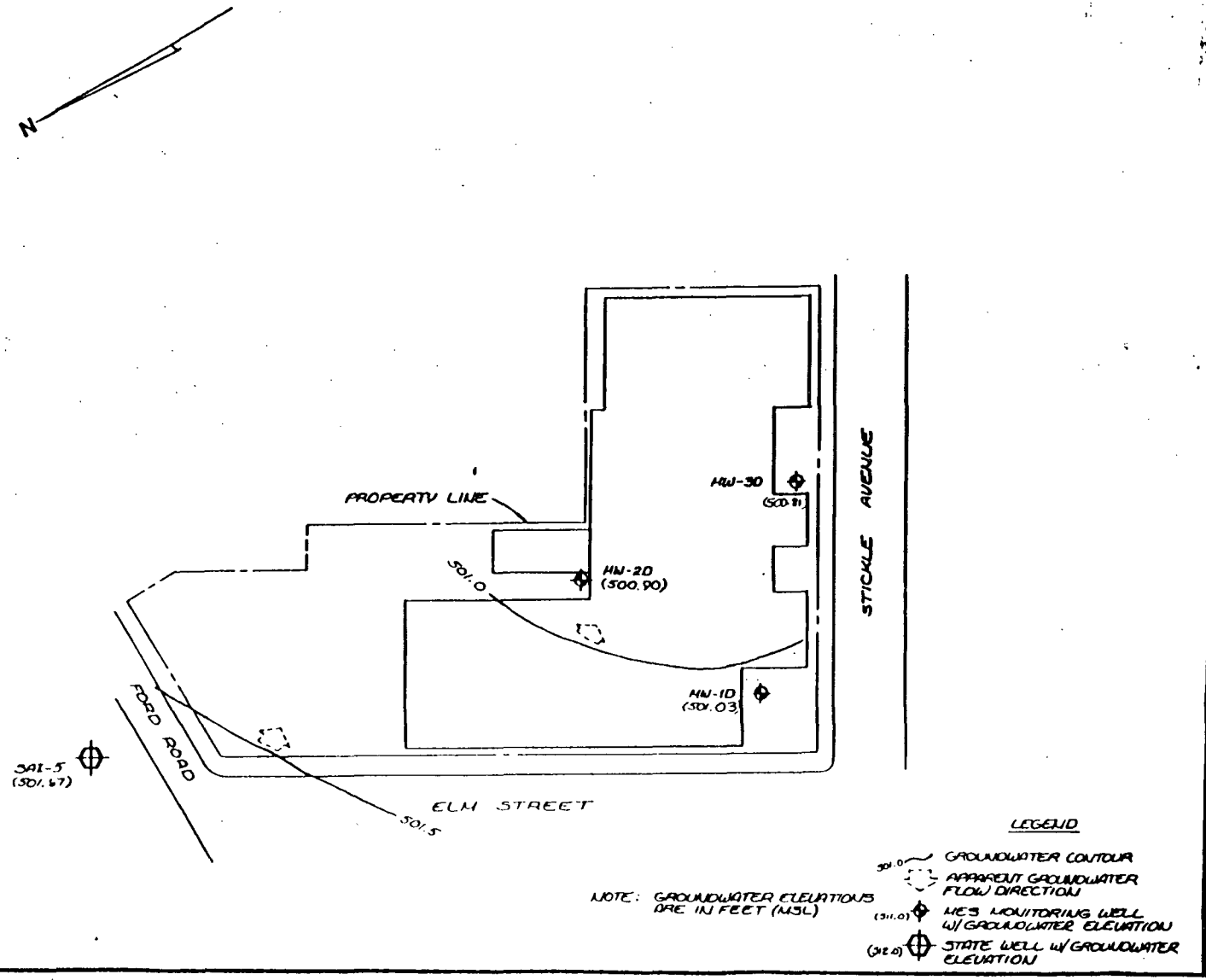
ROCKAWAY NEW JERSEY

RWY 002 1517



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ROCKAWAY NEW JERSEY

DEEP GROUNDWATER CONTOUR MAP
SAMPLING ROUND 2: AUGUST 7 - 10, 1987

FIGURE 8

DRAWN B. SPADY
SCALE 1"=60'
DATE 9/8/87

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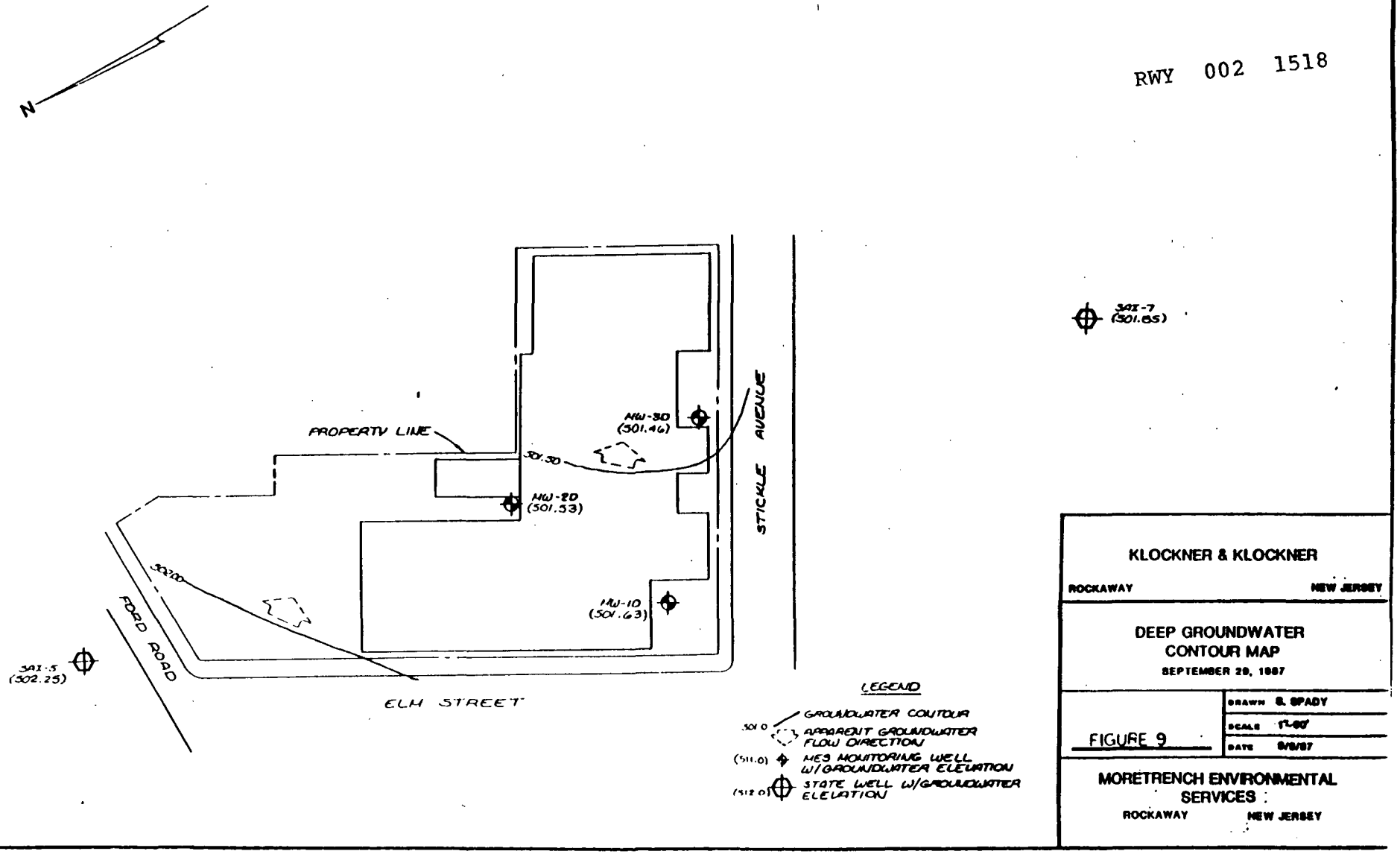
ROCKAWAY NEW JERSEY

RWY 002 1518



KLOCKNER & KLOCKNER

ROCKAWAY NEW JERSEY

DEEP GROUNDWATER CONTOUR MAP

SEPTEMBER 29, 1987

FIGURE 9

DRAWN S. SPADY

SCALE 1"=60'

DATE 9/8/87

MORETRENCH ENVIRONMENTAL SERVICES

ROCKAWAY NEW JERSEY

volatile organics were detected. Since deep aquifer contamination is part of the regional problem, it would best be addressed under CERCLA.

CATCH BASIN AND STORM WATER CONVEYANCE SYSTEM

Based on the results of the integrity test performed on the catch basin system, cleanup of this system and associated contaminated soils is proposed and will involve removal and disposal of the catch basin/storm sewer line and surrounding effected soils. The extent of soil contamination will be determined in the field with an Organic Vapor Analyzer (OVA) and/or Photovac TIP II and confirmed by laboratory analysis of selected soil samples. Upon receipt of negative laboratory results, a new storm water conveyance system will be installed.

Underground Tank #5

Based upon visual inspection, field readings with the OVA and confirmed by post excavation sampling, the tank was not leaking. No further investigation regarding tank #5 is proposed. Laboratory deliverables are attached as Appendix E. The results of the analyses are summarized in Table 3.

TABLE 3

SUMMARY OF POST-EXCAVATION
SOIL SAMPLING RESULTS

Sample No.	Sample Location	Sample Depth	Total Volatile Organics (EPA Method 503.1)
S-1	North end of base of excavation along tank spine	0-1' below tank invert	N.D.
S-2	Center of base of excavation along tank spine	0-1' below tank invert	N.D.
S-3	West sidewall of excavation	0-1' below tank invert	N.D.
S-4	South end of base of excavation along tank spine	0-1' below tank invert	N.D.
S-5	East sidewall of excavation	0-1' below tank invert	N.D.
S-6	Duplicate of S-5	0-1' below tank invert	N.D.

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RECOMMENDATIONS

As a result of implementation of the revised sampling plan, volatile organic compounds, primarily TCE, were detected in the shallow and deep aquifers beneath the Klockner property. An abbreviated wellpoint recovery system in the vicinity of the previous tank #4 and current catch basin system locations is suggested to capture and contain the shallow aquifer contamination. If necessary, the recovered water will be treated prior to disposal. In addition 3 shallow (less than 25-30 feet) upgradient borings are recommended to determine the extent of the confining clay/silt layer separating the shallow and deep aquifers. Currently, there is no indication that there might be an upgradient source contributing to the deeper aquifer contamination problem. Installation of a deep monitoring well in a more upgradient location (near MW1S and the catch basin system) is recommended to determine the extent of deep contamination. Due to the status of this site being investigated both under ECRA and CERCLA a meeting between all concerned parties is recommended to discuss the requirements which will be made for on-site cleanup of groundwater. After such meeting a Cleanup Plan will be prepared.

State of New Jersey

DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF WASTE MANAGEMENT
HAZARDOUS SITE MITIGATION ADMINISTRATION
CN 028, Trenton, N.J. 08625

MARWAN M. SADAT, P.E.
DIRECTOR

JORGE H. BERKOWITZ, PH.D
ADMINISTRATOR

Mr. Gary Cluen
Ground/Water Technology, Inc.
90 Stickle Ave.
Rockaway, NJ 07866

03 APR 1986

RE: Masden Industries - Multiform Metals Division
Stickle Avenue and Elm Street
Rockaway Boro, Morris County
ECRA Case #85551

Dear Mr. Cluen:

Please be advised that all materials itemized on the attached list must be legally disposed of or otherwise accounted for. The Department will require clear documentation for each item. If such documentation is not provided it will be assumed that the materials have been illegally disposed of and appropriate enforcement actions will be initiated.

Be further advised that all conditions and deficiencies outlined in the inspection report and in any other correspondence from this office must be addressed to the satisfaction of the Department before a Negative Declaration or Cleanup Plan can be considered for approval.

Further questions in this matter should be addressed to Michael Surowiec at 609-633-7141.

Sincerely,

Richard J. Katz, Assistant Chief
Bureau of Industrial Site Evaluation

HS154:kc
cc:

shipped to Huth

+ Dynaglass is same as shipped to Huth

X Substances on Hasden Ind. fire dept report

Wastes found in sled

1- 55 gal with drum pump - empty
1 - 55 gal multi purpose gear oil - material in it.
1- 55 gal unknown substance in it
1- 5 gal pail Acetic Acid
1 - 20 gal fiber drum - Copper Cyanide
2 - 90 lb. Carboys - Ammonium Hydroxide
1 - 20 gal fiber drum - Rodine 50
5 - 5 pint containers in a box Hydrochloric Acid
1 - 5 pint container in box Sulfuric Acid
3 - cardboard boxes unknown contents
1 - ~20 gal keg like container - oxidizer
1 - 20 gal. - black plastic drum made out to Dynaglass Inc
1 - 20 gal - white plastic container Fluoboric Acid
1 - 5 gal. plastic bottle - ½ full red liquid
1 - 55 gal fiber drum with ⅗ white powder and a 5 gal empty clear plastic bottle sitting inside on powder
1 - 55 gal miscellaneous material
1 - 20 gal fiber drum - paper + lab ware debris
1 - 20 gal - rusted drum, label not readable
2 - 5 gal pails stacked one on top other; "Oxidizer" on top; white crystal formed material protruding from between drums; bottom drum rusted & no label visible
1 - white styrofoam pack - nitric acid

RWY 002 1523